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The Journal

of the

AMERICAN LEATHER CHEMISTS ASSOCIATION

Vol. LIV JUNE 1959 No. 6

CONTENTS

The Significance and Precision of Results from the Application of the Tensile Test to Leather - - - - - - - - - - - - - - *By* ROBERT M. LOLLAR 306

ALCA News - - - - - - - - - - - - - 356

Abstracts - - - - - - - - - - - - - 368

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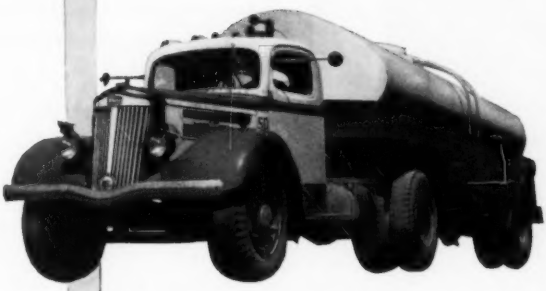

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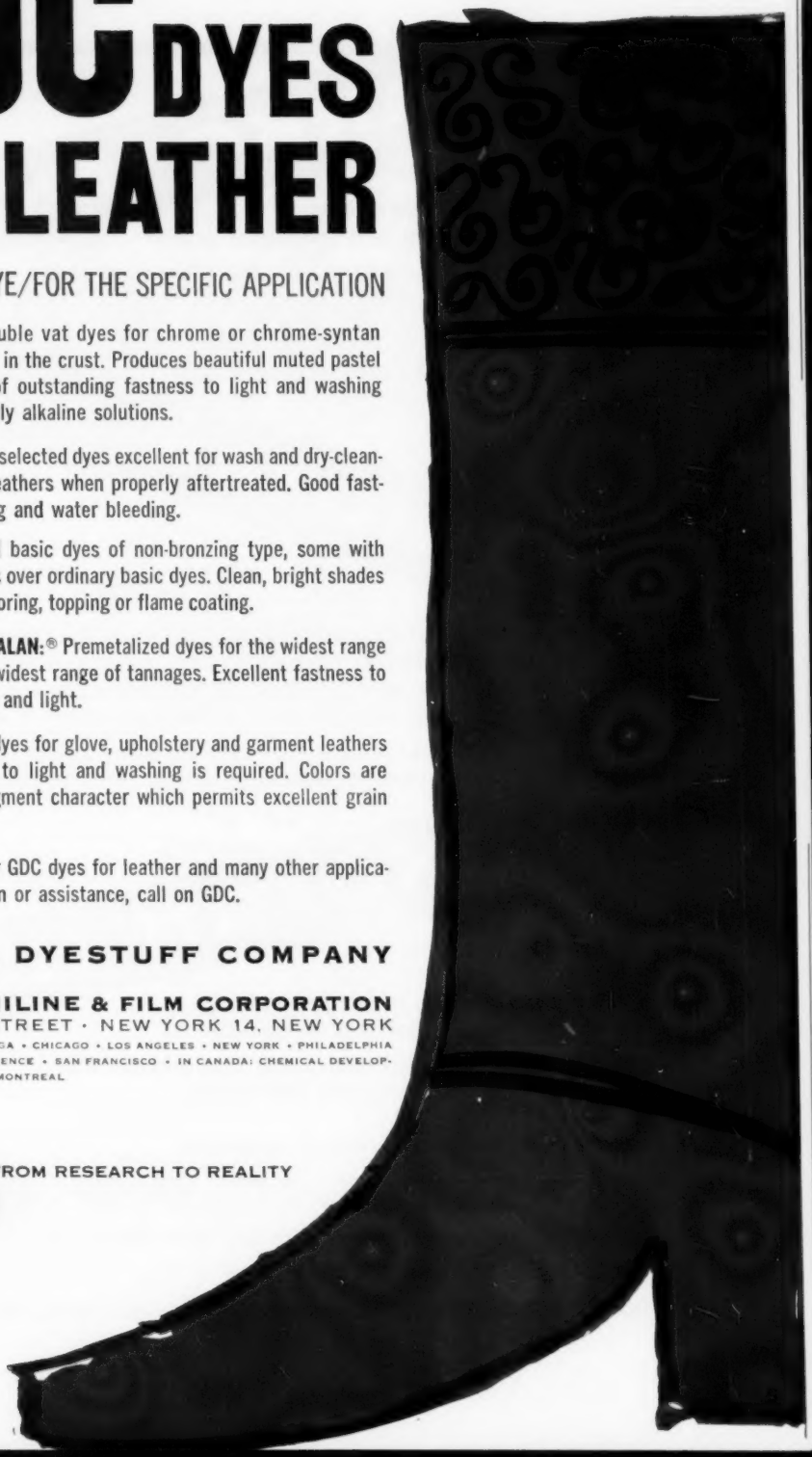

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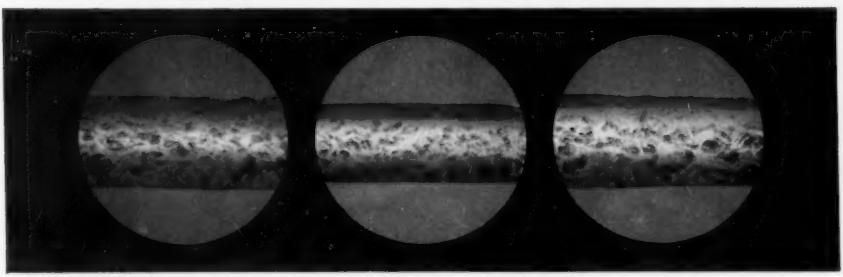

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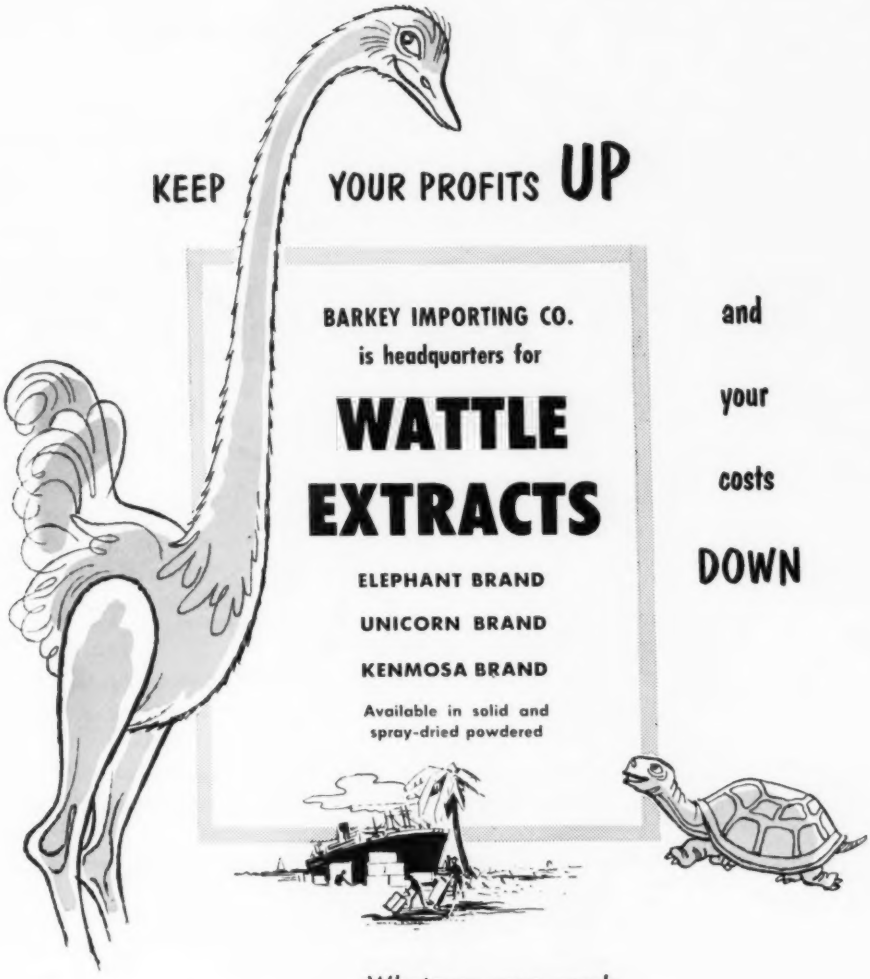

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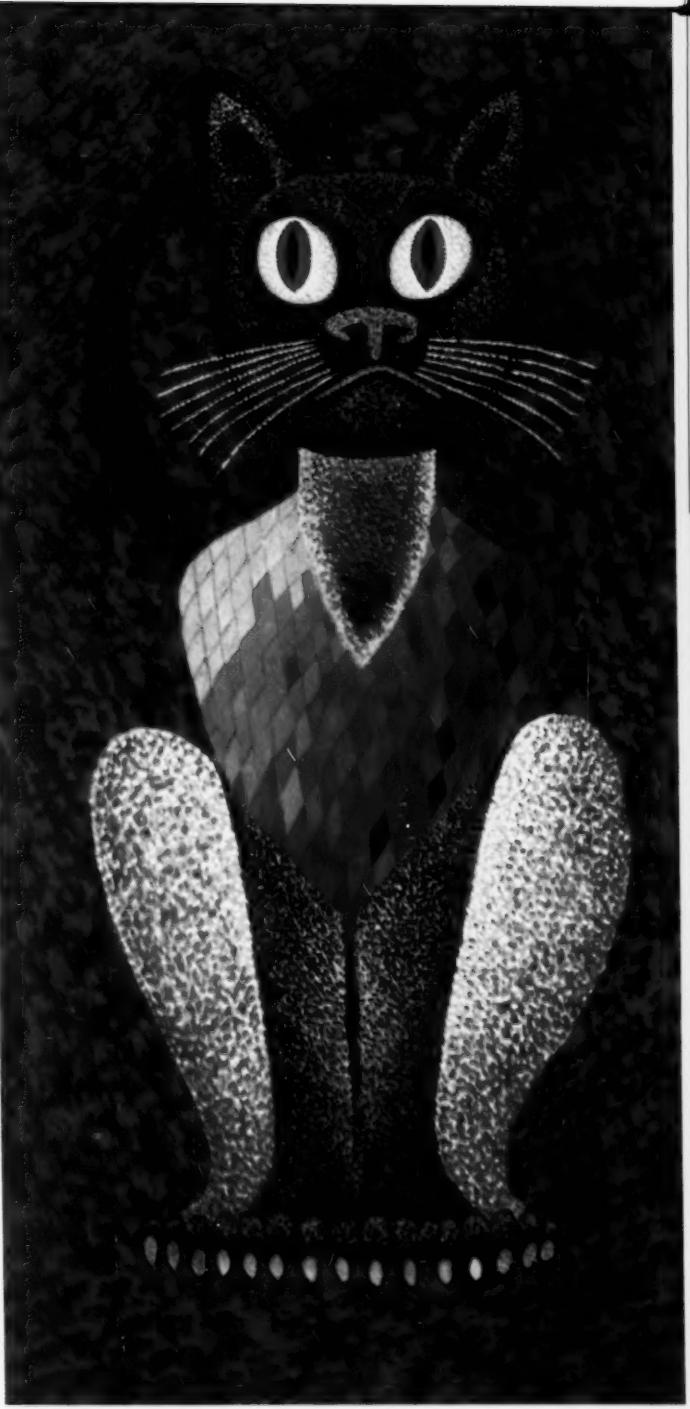

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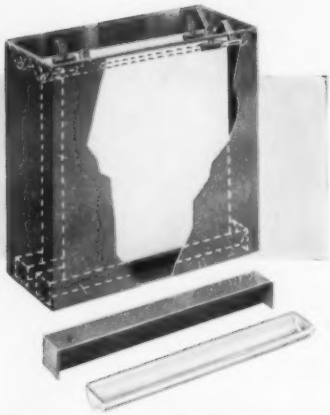

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THE SIGNIFICANCE AND PRECISION OF RESULTS FROM THE APPLICATION OF THE TENSILE TEST TO LEATHER*

ROBERT M. LOLLAR

Tanners' Council Research Laboratory†
University of Cincinnati
Cincinnati 21, Ohio

ABSTRACT

A critical examination has been made of the tensile strength test for the estimation of leather quality; particular emphasis has been placed upon the significance of the results obtained and their anticipated precision. Recommendations are made for the modification of certain details of the calculation of the results obtained; the modification does not make the inefficient assumption that the tensile breaking load is linearly dependent upon the specimen cross-sectional area. Furthermore, the suggestion is made that the more convenient method E17A for the determination of elongation be substituted for the more laborious, less precise method E17. Finally, the value of certain other parameters of the stress-strain curve related to the work required to break the leather is suggested.

—×—×—

INTRODUCTION

The official methods of the American Leather Chemists Association (2) include a method entitled "Tensile Strength" under the code number of E15; associated with this method is the method for the determination of the stretch of the leather under tension, which is entitled "Elongation" and coded E17. The Association, in cooperation with the American Society for Testing Materials, has created the Joint Committee on Leather which has the responsibility of development of methods for the determination of the physical properties of leather, which methods may be adopted by both associations. This Joint Committee has certain requirements for the form of the written descriptions of the methods; hence, a re-examination of the test methods described in the official methods of the Association is necessary.

*Presented in part at the Fifty-fourth Annual Meeting of ALCA at the New Ocean House, Swampscott, Mass., May 25–28, 1958.

†Dr. Lollar is Now Technical Director of Armour Leather Company, Chicago, Ill.

The author of this paper, serving as chairman of the Joint Committee's Subcommittee I on "Nomenclature, Definitions and Applicability", had to re-examine critically our methods of test. This paper presents the results of this re-examination of the tensile strength method.

LIFE LINES

Dr. Robert M. Lollar became Technical Director of Armour Leather Co. in January of this year. Previous to that time he was an associate professor in the Department of Tanning Research and a member of the staff of the Tanners' Council Research Laboratory, both at the University of Cincinnati where he earned his M.S. and Ph.D. degrees. Dr. Lollar has been a frequent contributor to this *Journal*, and until recently he served as one of its regular abstracters. In 1954 ALCA presented him the Alsop Award.

The statement of policies adopted by the Joint Committee was taken from a report in early 1957 (3) by the ASTM Committee E-1 on "Methods of Testing". The portion of this report which is pertinent in this discussion was entitled "Significance of Test" and included the following:

> 3. (a) This section shall include formation explaining the usefulness of each test procedure described, including the range and limitations of materials, conditions, and expected applications covered by the method. Such statements should be concise without sacrificing important ideas or completeness. They should be adequate to provide the user of the method with a full understanding of the test results.
>
> (b) The following features should be considered in preparing this section of Significance:
>
> (1) The specific meaning of the test results as related to the manufacture and end use of the material,
> (2) The general effects of variations in test conditions on the expected test results,
> (3) The suitability of the test for research, development, manufacturing control, specification acceptance, and service evaluation,
> (4) The limitations or fundamental assumptions inherent in the method which may affect the usefulness of the results,
> (5) A comparison with significance of other tests of a similar nature, if such are available, and
> (6) An indication of the range of precision or accuracy expected of the test results.

While the official methods of the Association contain some information which is pertinent to the above six points, they are not complete with reference to all the points. In particular, the methods contain no information on the precision and accuracy of the test results from the methods. However, the published literature does contain considerable information on these topics; furthermore, the files of the Tanners' Council Research Laboratory also contain additional information relevant to these points. This paper will present a critical review of this body of information with reference to the tensile test method.

THE GENERALIZED CHARACTERISTICS OF THE TENSILE TEST

The tensile test is an ultimate strength test which consists of holding the two ends of a long specimen, which usually has a dumbbell-shape, and pulling them apart until the specimen breaks. Test machines of several kinds are employed in this test; many of these machines are equipped with devices which record autographically the load-extension, or stress-strain, curve for the entire response cycle of the specimen to the elongation. It is customary to report the results in terms of the rupture load per unit initial cross-sectional area of the specimen.

Alfrey (1) has observed that the interpretation of the tensile, or ultimate, strength of high polymers is limited by three difficulties:

(*a*) Since the rupture process is a discontinuous process, it is never possible to describe mathematically a breaking process in the sense that it is possible to describe an elastic deformation or a viscous flow. Thus, the ultimate strength of a fabric is not as useful from a theoretical basis as those parameters which describe the stress-strain curve of the material.

(*b*) Ultimate strength is intimately connected with nondominant, nonlocal structural characteristics of a material, in contrast to the elastic constants of the material which depend on the dominant local structure which can be most readily determined, as, for example, by X-ray methods. As a result, "theoretical" ultimate strengths for a polymer calculated on the basis of dominant local structures are invariably several orders of magnitude too high.

(*c*) Finally, and perhaps as a corollary of item (*b*), the data secured for ultimate strength show greater scatter, or dispersion, than do data for parameters which describe the stress-strain curve of the material. The structural features which control ultimate strength are strongly affected by fortuitous and uncontrollable small differences in the material being tested.

The ASTM specifications for textile testing machines (4) note that tension testing machines may be generally classified as operating on one of the following three principles:

(*a*) Constant rate of traverse, as in the pendulum machines.

(*b*) Constant rate of load, as in the inclined plane machines.

(*c*) Constant rate of specimen extension, as in those machines in which a fabric-extending crosshead is driven at constant rate regardless of the resistance of the specimen to extension.

The operating conditions on these several machines may be varied within certain limits, so that the duration of the test on a given specimen is variable. This is a significant factor in the specification of the test method, since impact loading may be secured during a rupture test of very short duration, while creep phenomena may exert a significant influence on the results if the test duration is very long.

Reichardt *et al.* (34) have observed that in the laboratory determination of the load-extension properties of fabrics the customary techniques consist mainly of application of the load in one direction and the measurement of the strain in that direction. They have described an auxiliary device for use on a currently available constant-rate-of-specimen-extension tensile tester to impose simultaneous extension to the specimen in two mutually perpendicular directions. Another special case for the tension testing of a fabric would be that which results when the bursting strength of the fabric is determined by the application of force perpendicular to the deformed surface, such as the familiar Mullen bursting strength test. In this test the surface of the specimen opposite to the point of force application undergoes extension until failure occurs; the portion of the specimen adjacent to the deforming tool undergoes a more complex combination of compressive and tensile forces. In any event, it is characteristic of this test method that the application of the tensile force is multidirectional rather than unidirectional as it is in the conventional stress-strain test.

Study of the stress-strain relations which result in the extension of textile fibers has yielded considerable information on the factors which influence the ultimate, or tensile, strength of the fibers. Mark (25), Dillon (12), and Meredith (27) have reported data on this subject, emphasizing especially the effect of such factors as the composition and the structure of the fiber, its condition during testing (whether wet or dry), the rate of extension, and the relative humidity and temperature that is ambient during the testing. Similar studies on fiber composites or fabrics are not so plentiful. However, reports by Susich and Backer (44) for textile fibers and by the staff of the Institute of Paper Chemistry (19) may be cited, since they contain information that is germane to this discussion.

THE DETERMINATION OF THE TENSILE STRENGTH OF LEATHER

Spiers (42) reviewed the early literature on the physical testing of leather, presenting 76 references published through 1930 on the determination of the tensile properties of leather. He was able to trace the use of mechanical testing of leather back to 1884, when the tensile strength and stretch of belting leather was recorded. Wilson (48) reported in 1929 upon the initiation of committee efforts by the Association to recognize, name, measure, and catalog important properties of representative leathers. Lollar (21) in 1940 reviewed the physical testing of leather, presenting information on factors which influence the determination of the tensile properties of leather. Reference to these reviews will assist those who are interested in the early history of tensile test methods as applied to leather.

In 1937 Emley (13) published a series of methods for measuring the physical properties of leather, including the determination of tensile strength, elongation, and tearing strength. A footnote indicated that the methods were

published to elicit criticism. The American Leather Chemists Association adopted a modification of the tensile strength method as provisional in 1941 (5); after further amendments this became an official method in 1943 (2a). In 1948 a joint committee was appointed by the Association and the Federal Specifications Board to revise and rewrite the existing physical testing methods for leather and if possible to work out a single set of methods acceptable to both groups. In 1953 Maeser (26) presented a revision of the physical testing methods which resulted from this action. Method P15 of this revision became a provisional method of the Association in 1953 and official method E15 in 1956. This method is equivalent to Method 2011 of the Federal Specifications (14) and to similar methods by other associations interested in leather chemistry, as, for example, the method given in Section 17 of the Official Methods of Analysis of the Society of Leather Trades' Chemists (41).

Throughout the several revisions of the Association's method in the twenty-year period, changes were made in the details of the method to reflect the results of the committee studies during the period. Some of this work has appeared in the form of independently published articles, while other portions of the work have merely been alluded to in the minutes of the Association's Physical Testing Committee. This paper will present certain of this information which the Joint Committee on Leather has requested in a methods discussion.

THE PRACTICAL SIGNIFICANCE OF TENSILE STRENGTH TESTS UPON LEATHER

Spiers (42) has noted that the determination of the tensile strength of belting leather by Bach is one of the earliest recorded uses of a mechanical property test of leather. The strength of leather has continued to be of particular concern in the production of belting, strap, and harness leathers; however, the concept has been applied to all types of leather. Thus, Beek (8) noted that "tensile strength is one of the properties which determine the utility of leather." He further observed that measurement of the tensile strength is generally used as a criterion of leather quality, as an aid in the assessment of the effect of different processes on the quality of leather, and as an aid in the evaluation of the extent of deterioration of leather exposed to different environmental conditions.

One can conclude in general that the better-quality leather of a particular type is that leather whose strength is greatest. However, it is difficult to define the minimum limit for strength which defines an acceptable quality level for a particular leather. We have noted earlier that the tensile strength of any substance is merely a calculated value determined from the dimensions of the test specimen and the load applied to it at the instant during the load-extension curve when specimen rupture occurs. Many of the useful properties of leather are far more dependent on the nature of the initial, or low

load, portions of the load-extension response curves than they are on the ultimate strength of the specimens. Hence, while each leather must possess a certain level of tensile strength if it is to be acceptable, leather generally possesses strength in excess of its service demands. This is particularly true when one considers the *average* tensile strength of a lot of leather. It is the proportion of the lot which has the minimum strength which is of greatest concern when one examines experimental data on the tensile properties of leather rather than the average strength. This, therefore, requires that a valid estimation of the tensile strength of leather must report not only the central tendency but also the dispersion of the tensile strength values for the lot of leather. More evidence on this question will be presented later.

The value of tensile strength tests on leather as a general quality indicator is limited by the fact that the application of extending loads to portions of leather in practice can take place in quite random orientations with respect to such hide factors as the direction of the backbone line or the direction of alignment of the hair follicles. In certain leathers, such as belting or strap leathers, the use conditions define the direction of application of the deforming load, and it is thus possible to test such leathers for their tensile properties in the same direction. However, in leathers such as shoe upper leathers, the orientation of the application of the deforming loads is more nearly random with reference to the hide directions; furthermore, the use conditions of loading often result in greater tension being applied to the grain of the leather than to its corium fibers. It has, therefore, been found that the Mullen grain crack strength and the subsequent bursting strength of the same specimen is more valuable in the evaluation of the quality of shoe upper leather. Thus, this method or its alternate, the ball bursting strength, is included in the official methods of the Association (2) and in the Federal Specifications methods (14).

Mitton and Hall (29) have noted that "in many uses to which leather is put, its ultimate mechanical failure is due to a tearing action of some kind or other." Hence, several different kinds of tension tests have been applied to leather, as inspection of the industry's methods booklets (2, 14) will show. This paper will consider some known interrelationships between the several methods of tension testing of leather.

The tensile strength test possesses, along with all methods for the determination of the ultimate strength of leather, the deficiency that it involves loading the specimen to failure in a single application of load. Yet, leather as a useful fabric must withstand many applications of load each of which is less than the ultimate load to rupture it; the permanent deformation under these loads becomes the significant quality criterion. This deficiency was emphasized to the author by a problem referred to the Laboratory which concerned the determination of the proper time to cease use of lineman's safety-belts. Belts which had been in service and which had obviously

TABLE I

CHARACTERISTICS OF THE LEATHER USED

Leather Code	Thickness mils	Description of Leather			Analyses of Leather (Reported on the as-received basis)	
		Color	Finish	Temper	Moisture, %	pH
P1	88	Mahogany	Pigment finish	Firm	8.32	3.04
P2	70	Brown	Pigment finish	Firm	11.78	3.32
P3	60	Beige	Full grain	Firm	10.60	3.95
P4	72	Brown	Full grain	Soft	11.65	3.55
P5	114	Black	Boarded grain	Semisoft	11.29	3.54
P6	100	Tan	Snuffed grain	Soft	11.32	3.31
P7	68	Tan	Snuffed grain	Soft	11.15	3.32
P8	53	Blue	Snuffed grain	Firm	11.41	3.42
P9	46	Tan	Snuffed grain	Firm	10.68	3.74
P10	97	Black	Embossed grain	Soft	11.80	3.18
P12	59	Brown	Snuffed grain	Firm	10.69	3.58
P13	82	Tan	Snuffed grain	Semisoft	11.41	3.78
P14	98	Brown	Full grain	Firm	11.11	3.63
P15	86	Tan	Snuffed grain	Firm	9.62	3.02
P16	45	Brown	Full grain	Firm	12.47	3.23
P17	95	Tan	Corrected grain	Semisoft	12.13	3.55
P18	76	Beige	Corrected grain	Firm	11.96	3.36
P19	57	Beige	Snuffed grain	Firm	12.91	3.12
P20	71	Grey-blue	Snuffed grain	Firm	11.94	3.43
P21	69	Brown	Corrected grain	Firm	12.93	3.38
P22	57	Brown	Snuffed grain	Soft	12.27	3.35

undergone mechanical damage as indicated by their deformation and by fiber rupture in the grain area could not be distinguished from the original belts by the tensile strength data which were obtained. These observations suggested that the results secured from repetitive addition of subdestructive tensile loads to leather specimens should yield a valuable indicator of leather quality. Vickers (46) has reported a dynamic stitch tear fatigue test for leather, but an equivalent study has not been reported for the specimen loading conditions which apply in the tensile strength determination.

A preliminary experiment has been conducted which has given some information on the tensile strength test on leather. Twenty-one different pieces of shoe upper leathers of widely different composition, thickness, and commercial leather quality (feel, color, grain finish, etc.) were available from laboratory work on other problems. Each piece had been taken from the kidney area of a side; the pieces were about 18″ long parallel to the backbone and 12″ wide perpendicular to the backbone. The pieces, referred to under a code number, were selected as specific leather specimens; generalization of the results will necessitate further examination of many sides of several leathers. The results presented here are given with particular reference to the tensile test method rather than with reference to the particular leather. The wide variety of leather was included to insure that variation in the salient characteristics of the leather would be large enough to assure detection of differences in this preliminary study.

Tables I and II present a summary of certain characteristics of the 21 leather specimens included in the study. Inspection of these tables discloses the expected dissimilarity of the different leathers. Thus, leather P1 is obviously a stuffed, chrome vegetable-retanned leather; at the other extreme in composition, leather P16 is chrome-tanned with minimum addition of vegetable mordant, dye, and fatliquoring oils to the chrome-in-the-blue stock. P16 is noted to contain almost twice as much hide substance as leather P1; this large a difference in the dilution of the hide substance fibers during tannery processing should be expected to yield significant differences in leather properties.

Six official ALCA dumbbell-shaped tensile strength specimens were cut from each of the 21 different kidney-area blocks of leather. These dumbbell-shaped specimens were cut with their long dimension paralled to the backbone of the block, with the 6 different specimens being taken in a row perpendicular to the backbone. Care was taken so that all 6 specimens came from a rectangle of leather about 7.5″ square for each of the 21 leathers. Then, 3 of the 6 dumbbell-shaped specimens were selected alternately for determination of the tensile strength according to ALCA method E15. The alternate 3 specimens were subjected to mechanical cyclic extension without rupture prior to being tested for their tensile strength. The Instron tensile testing

instrument (Model TT-B), a machine which yields constant rate of specimen elongation, was used in this work.

TABLE II

CHEMICAL COMPOSITION OF THE LEATHER USED

Leather Code	Chromic Oxide (Hide substance basis) %	Composition of Leather—Dry Basis			
		Total Ash %	Hide Substance %N × 5.62	Grease % Chloroform Soluble Extractive	Combined Organic Matter %*
P1	6.06	5.17	43.7	27.5	18.7
P2	3.55	4.38	76.4	5.50	8.0
P3	7.16	6.93	63.4	12.4	7.3
P4	5.39	4.37	71.1	7.86	9.8
P5	4.40	3.84	79.3	5.29	5.5
P6	5.48	4.92	66.9	10.3	10.4
P7	5.72	5.07	71.1	10.2	5.8
P8	6.02	6.47	75.6	6.58	3.3
P9	6.34	11.26	60.7	11.2	8.8
P10	7.09	5.33	68.6	13.9	2.8
P12	4.77	5.08	74.4	8.52	4.4
P13	5.80	7.93	73.6	5.80	4.9
P14	7.62	6.10	69.6	12.77	1.2
P15	2.76	8.29	63.3	8.66	15.6
P16	4.63	4.49	85.2	3.60	— 0.4
P17	4.26	4.26	83.5	5.41	0.0
P18	4.63	9.97	75.0	8.10	0.4
P19	6.90	6.12	81.4	5.37	— 2.7
P20	4.92	3.74	64.1	10.86	14.2
P21	4.39	6.96	76.0	6.32	4.5
P22	5.05	4.79	76.6	7.32	3.4

*Kubelka factor (20) used to calculate the total mineral tannage; this value is the unaccounted-for residue required to yield a material balance.

The rate of crosshead travel was set at 10″ per minute to satisfy the requirements of the ALCA method; since the initial jaw separation was 5″, the rate of specimen extension was 200% per minute. The extension was recorded with a twofold magnification so that it was possible to read to the nearest percent the percent extension directly from the stress-strain curve on the instrument chart. The choice of load-measuring cell and range thereof resulted in a chart in which 10″ represented 200 lb. of breaking load (except for sample P5 which required the 500-lb. scale); it was, therefore, possible to read the breaking load to the nearest pound. Frequent calibration throughout the work insured this accuracy.

The area enclosed by a stress-strain curve and the strain axis is an estimate of the work required to extend the specimen; the total area under the stress-strain curve carried to the point of specimen rupture is known as the work of rupture. This work of rupture was estimated for the 63 tensile strength specimens by measurement of the area under the stress-strain curves with a polar planimeter. These values were used to determine a mechanical cycling program to apply to the alternate 63 specimens. This program was designed to apply 50% of the work to rupture to the specimen during the first mechanical cycle, a total of somewhat less than 100% of the work to rupture during the first 2 cycles, and a total of 200% of the work to rupture during 5 cycles. While the necessary extension varied from specimen to specimen, it was found that a cyclic extension of about two-thirds of the breaking extension approximated the above program. Since the 5 cycles of extension and relaxation were carried out continuously at a crosshead speed of 10″ per minute, and since the usual 5″ initial jaw separation was used, the 5 extension and relaxation cycles required a total of three to four minutes for each specimen. The 63 stressed specimens were then allowed to relax without any applied tension of standard conditions of temperature and humidity (73° F., 50% R.H.) for one month. These mechanically stressed specimens were subjected to the usual tensile strength test after this relaxation period.

The specimens were quite obviously damaged by the cyclic strain even though rupture of the specimens had not occurred during the application of twice the estimated rupture work for the specimens. This damage was demonstrated by strain lines and even grain cracks on the grain surface of the leather. Furthermore, the specimens had undergone permanent deformation, since they did not relax to their unstressed length during the one-month period.

The data secured in this experiment appear in Fig. 1, 2, 3, and 4; these data are presented as average values for the three or more replicated values that were secured. Since the mechanical stressing of the leather had irreversibly reduced the cross-sectional area of the specimens, the breaking strength data are reported in pounds of breaking load instead of pounds per square inch of cross-sectional area. It will be noted that the load to break has *increased* as a result of the application of cyclic strain to the specimens; expression of the results in pounds per square inch of specimen cross-sectional area at the time of rupture would have increased the apparent elevation of the strength.

This increase in the load to rupture the specimens as a result of the mechanical stressing of the specimens was found to be statistically significant as a result of the application of the analysis of variance technique to the data. This result confirms the deficiency of the tensile strength test which had been detected in the examination of the damaged lineman's belts. Therefore, it

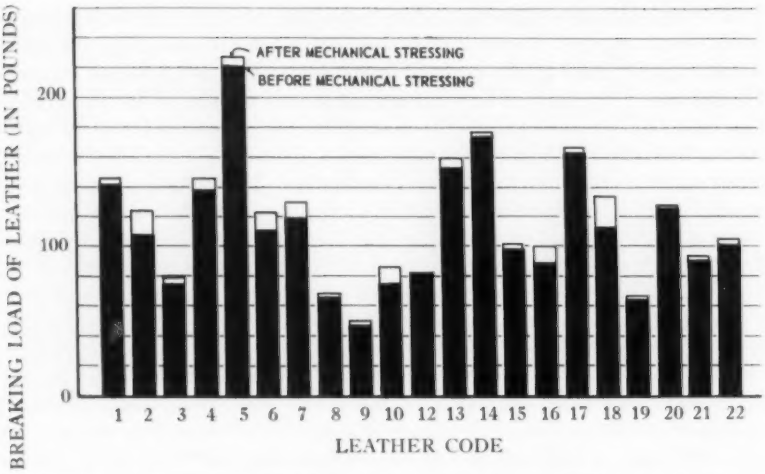
AFTER MECHANICAL STRESSING
BEFORE MECHANICAL STRESSING
BREAKING LOAD OF LEATHER (IN POUNDS)
200
100
0
1 2 3 4 5 6 7 8 9 10 12 13 14 15 16 17 18 19 20 21 22
LEATHER CODE

FIGURE 1.—Response of leather to mechanical stressing. Tensile breaking load.

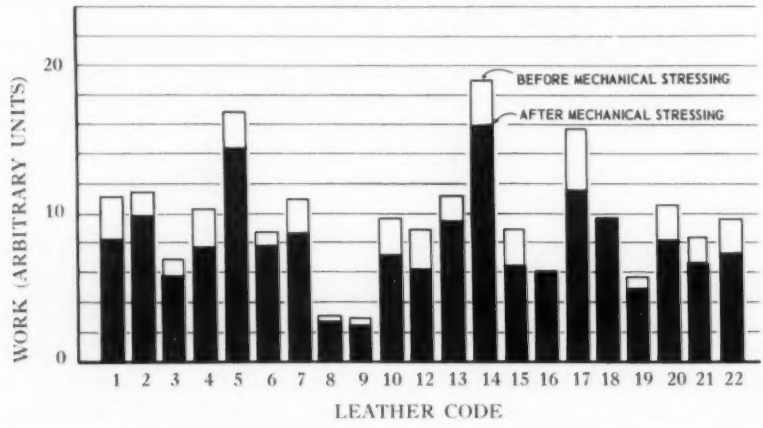
BEFORE MECHANICAL STRESSING
AFTER MECHANICAL STRESSING
WORK (ARBITRARY UNITS)
20
10
0
1 2 3 4 5 6 7 8 9 10 12 13 14 15 16 17 18 19 20 21 22
LEATHER CODE

FIGURE 2.—Response of leather to mechanical stressing. The work to break the leather estimated from the area under the stress-strain curve.

seemed desirable to consider other parameters to characterize the stress-strain response of leather to see whether they might not be able to detect this damage.

The first comparisons considered the elongation necessary to rupture the specimens. It was found to have been decreased by the 5 applications of

cyclic strain. This decrease was found to be statistically significant, which would be expected in view of the observed permanent deformation of the specimens.

Figures 2 and 3 further reflect the damage to the leather; these figures present measures of the toughness of the leather. The data have been presented in arbitrary units in each case. The work to break the specimens (Fig. 2) is given in square inches of enclosed chart area; the magnitude of this number is, of course, dependent on the scalar system used to record the stress-strain curve. The toughness index (39) has been defined as one half of the product of the load to break times the elongation of the specimen; these data (Fig. 3) are given in the arbitrary units which result when the fractional extension is multiplied by the breaking load in pounds. It will be observed that both of these parameters of the stress-strain response curve of the leather have detected the damage to the leather; these decreases in the toughness of the leather were found to be statistically significant.

Figure 4 presents a summary of the data secured. While the tensile breaking load of the leathers was *increased* by the mechanical stressing of the specimens, the damage to the leather shown by the appearance of the specimens is detected in their permanent deformation and in the decrease in the work to break and the toughness index.

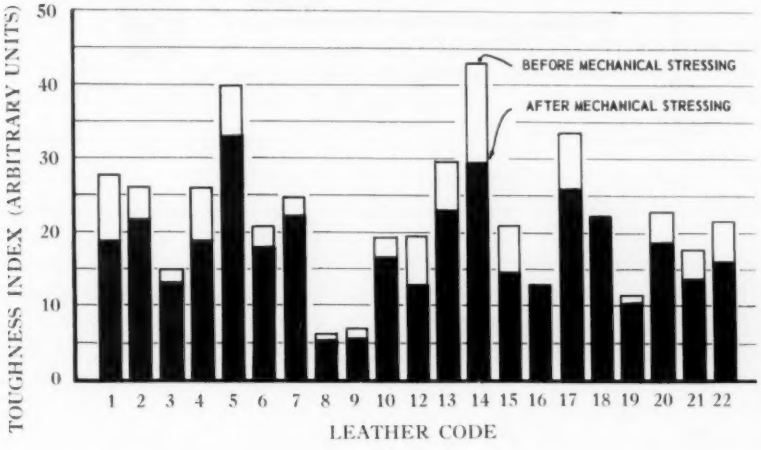

FIGURE 3.—Response of leather to mechanical stressing. Toughness index of leather calculated from

$$\frac{\text{breaking load} \times \text{elongation at break}}{2}$$

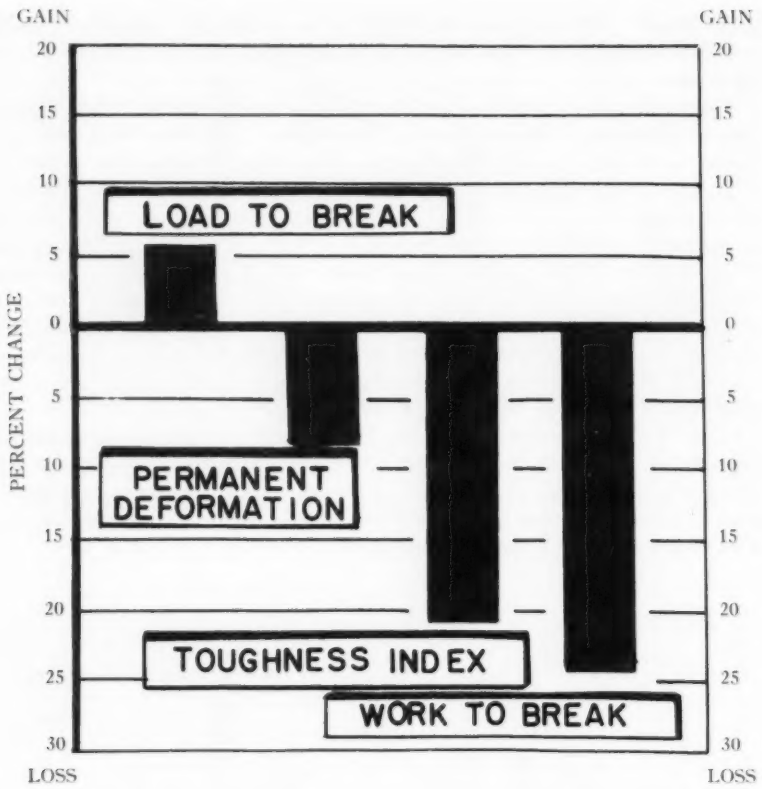

FIGURE 4.—Response of leather to mechanical stressing. Comparison of different quality indices.

These data, as well as the results secured in our earlier examination of the damaged lineman's safety belts, suggest that other parameters of the stress-strain response curve should be considered in place of the tensile breaking strength as criteria of leather quality. The two measures of toughness are particularly suggested, since they combine in a single term both the breaking strength and the breaking elongation of the leather. The work to break as estimated from the area enclosed between the stress-strain response curve and the strain axis is the most exact expression. Its determination is somewhat tedious if a planimeter must be used. It should be noted that the Instron tensile testing instrument is equipped with an accessory integrator which can record this parameter of the stress-strain response curve. How-

ever, the toughness index, calculated from the breaking load and breaking elongation, can be readily determined by any person testing the tensile strength of leather. Its deficiency as an index of toughness is that it assumes a linear response of the leather to extension. In the 21 shoe upper leathers examined here this was never exactly true. However, inspection of the data in Fig. 2 and 3 will show that the two measures of toughness of the leather before and after mechanical stressing gave very similar comparisons of the 21 leathers and their response to the mechanical stressing. Therefore, it is suggested that consideration should be given to a determination of the toughness of the leather as a measure of leather quality in the tensile strength test.

THE EFFECT OF VARIATION IN THE TEST CONDITIONS ON THE EXPECTED TEST RESULTS

While the use of tensile strength tests on leather has long assumed that tannery process conditions or environmental factors during use of the leather could influence its strength, it is also generally true that the inherent fibrous architecture of the leather must establish its strength. It is, therefore, logical that proper sampling within the skin or hide should concern those who use the tensile strength test. Since commercial use of leather from different areas of the same hide is established by the fibrous characteristics of the area, it is natural that these different areas would be regarded as significantly different areas for the purposes of testing. Thus, the first physical testing methods of the Association (2a) adopted in 1943 included five different sections for the sampling of different hide areas such as sides, bend, belting butts, bellies, and double shoulders. This concept continues to apply in the present method of the Association for the sampling of heavy leather for physical tests (Method J2) (2). However, a somewhat different concept has been adopted in the development of the present method of the Association for the sampling of light leather for physical tests (Method J1) (2). This method was based upon work reported by Mann *et al.* (24), who studied the properties of side upper leather to select the area within the side which was best able to reflect changes in the side average value for the test method under consideration. For tensile strength they found that the kidney area (their block 6) and a strip across the middle of the bend area (their blocks 12, 13, 15, and 16) met this requirement best. Fortunately, the results from all test methods suggested that the area along the backbone just forward of the root of the tail (2″ from the backbone and beginning 5″ from the root of the tail, and designated as test area W in method J1) could be used for the sampling of leather for all test purposes.

The use of leather must involve the distribution of the strength of leather over the entire area of the skin or hide. Hodus and Stubbings (18) have summarized data which indicate the advantages to be gained from the

assumption of bilateral symmetry across the backbone for experiments involving the determination of the tensile strength of leather. However, within the side, large variations in the tensile properties occur; these have been studied systematically by a few workers.

Wilson (48) presented data on 4 different skins of calf leather; 2 of these skins were chrome-tanned and 2 were vegetable-tanned. For each tannage, 1 skin was cut into tensile strength specimens oriented parallel to the backbone, and the other skin was cut into tensile strength specimens oriented perpendicular to the backbone. He also published (47) a drawing of the area of calfskin in which he indicates the characteristic location of strong specimens and of weak specimens.

Conabere and Hall (10) have studied the distribution of the strength of leather over the skin area, using 1 vegetable-tanned sheepskin, 2 chrome-tanned goatskins, and 1 chrome-tanned calfskin. They observed that the tensile strength of the skins was greater when the specimens were oriented parallel to the direction of hair growth and weaker when the specimens were oriented perpendicular to this direction.

Stather and Herfeld (43) and Mitton (28) have published contour maps for the distribution of the tensile strength of the leather over the side. Stather and Herfeld considered a variety of German leathers, conducting an extremely large number of individual tests to secure the data on which the contour diagrams are based. Mitton's work is concerned more particularly with the physical and chemical characteristics of vegetable-tanned belting leather. Tensile strength data are presented from four belting butts supplied by each of eleven tanneries; each of the 44 butts was sampled in 9 different locations for the testing. A contour pattern for the butts is presented; however, it would seem to have been established upon an intuitive basis, since the contour lines are drawn at 500-lb. intervals, i.e., at 3500, 4000, etc.

While the contour maps representing the work of the different authors have some characteristics in common, they do not yield an unique contour map which might be considered representative of the distribution of the strength of the leather over the area of the side. It is not clear what basis these authors used in the selection of the limits for their contour maps; it seems probable that rather arbitrary limits were set, which might have obscured the natural limits for the contour lines. Wilson (48) is the only author who has published his original data in a form which permits their statistical examination. His data were re-examined to ascertain the limits for the contour lines which would be set by the frequency distribution characteristic of the data.

A frequency distribution is determined by counting the number of items, or specimens, which lie in certain discrete, although arbitrary, portions of the over-all range of the variation of the variable that is being considered. Wilson's data for the 4 calfskins which he examined are calculated as kilo-

grams per square centimeter of cross-sectional area of the specimen. Approximately 200 specimens had been examined from each skin, and the strength was found to lie between 50 and 500 kg. per square centimeter for all the specimens. It was decided to use 25 kg. per square centimeter as the arbitrary size of the intervals into which the distributions would be divided. These frequency distributions were then examined on arithmetic probability paper (9) to determine the characteristic parameters of the distributions. This paper yields a straight line with data which represent a normal frequency distribution, which distribution often is found applicable for measurement, or variables, data. Furthermore, the median of the distribution is directly indicated on the paper as a measure of the central tendency of the distribution. Finally, the standard deviation, the appropriate estimate of dispersion for a normal frequency distribution, can be estimated from the scalar length for the variable being considered which lies between either 15.9 and 50% or between 50 and 84.1% of the frequency distribution. Figures 5 and 6 present Wilson's data (48) on the tensile strength of chrome- and vegetable-tanned calfskins upon this probability paper.

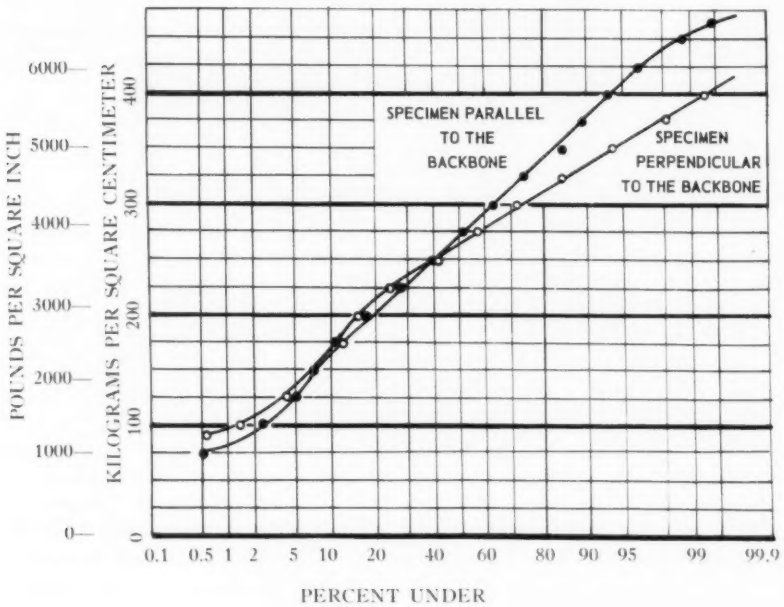

FIGURE 5.—Frequency distribution of the tensile strength of chrome-tanned calf leather over area of skin.

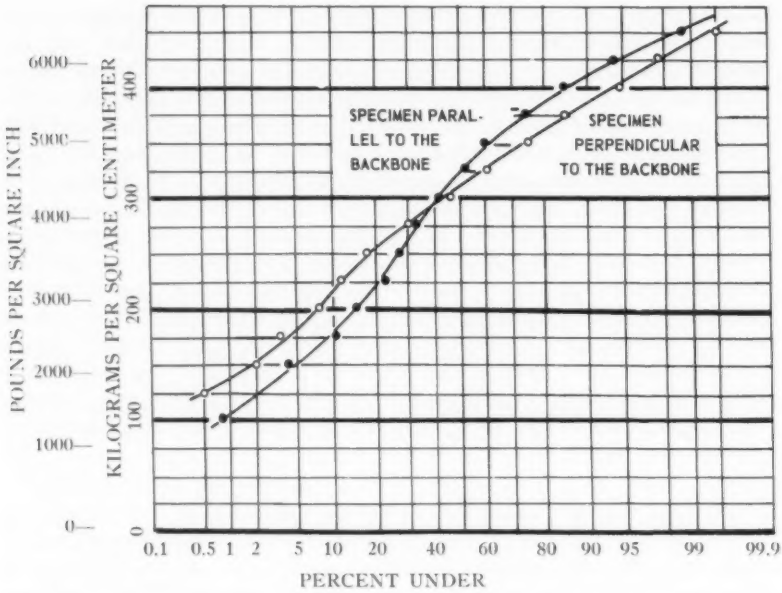

FIGURE 6.—Frequency distribution of the tensile strength of vegetable-tanned calf leather over area of skin.

The four frequency distributions do not yield precise straight lines. The concavity of the lower part of the curves, which is the most characteristic departure from linearity, reflects somewhat higher occurrence of specimens with low tensile strength than would be anticipated from the over-all distributions. Since only one skin was used for each tannage for each orientation of the specimens, no replication of the data is available. One can, therefore, make no statements about the comparative curves for the four skins; the observed differences could just as well be due to the skin difference as to specimen orientation or to tannage.

Considering the results as representative of the skins concerned, without attributing them uniquely to either tannage or direction of orientation of tensile strength specimens, four skin contour patterns can be constructed which are based upon the statistical parameters as estimated from Wilson's data by Figs. 5 and 6. It should be emphasized that in a normal frequency distribution, two thirds of all values lie within plus or minus one standard deviation increment from the central tendency of the distribution. Furthermore, within plus or minus two standard deviation increments, one expects to find 95.4% of all values. Finally, less than 27 values per 10,000 should

lie outside plus or minus three standard deviation increments from the central tendency of the distribution. Based upon these conclusions, it was decided to construct contour maps showing these contour areas:

a—Greater than 2 standard deviation increments below the median.
b—Between 2 and 1 standard deviation increments below the median.
c—Between 1 standard deviation increment below the median and the median.
d—Between the median and 1 standard deviation increment above the median.
e—Greater than 1 standard deviation increment above the median.

It will be noticed that three contour areas have been defined below the central tendency of the distribution, while only two contour areas have been defined above the central tendency. This was done deliberately because it is

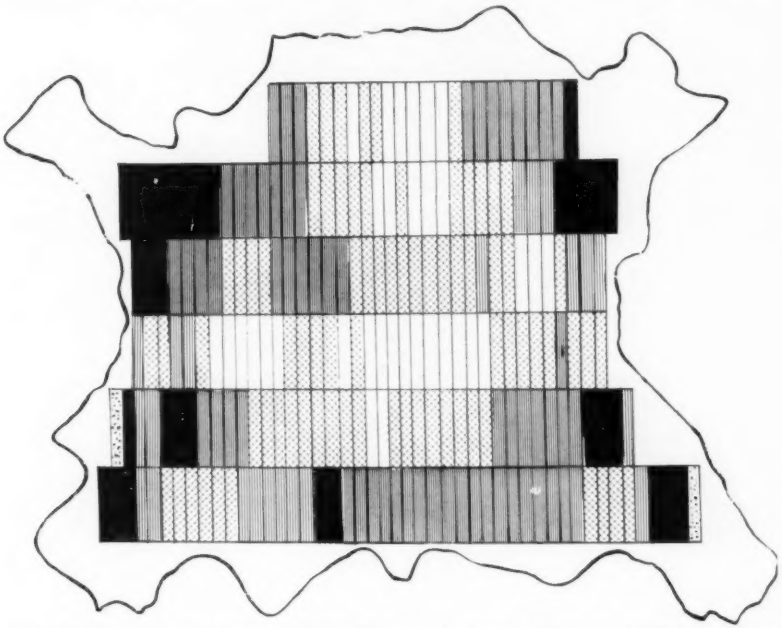

FIGURE 7.—Contour diagram for tensile strength of vegetable-tanned calfskin. Specimens parallel to backbone.

the fraction of the leather that is particularly weak which causes the most problems in the use of the leather. Since only one-sixth of the distribution should lie above a limit defined by one standard deviation above the median, there would be little opportunity to capitalize upon the exceptionally strong areas in actual use of the leather.

Figures 7, 8, 9, and 10 present the contour maps for the calfskins tested by Wilson (48) when these contour areas are defined by the statistical parameters of the distributions. It will be observed that these contour maps do not agree with Wilson's contour map (47). Two factors should be considered in this regard. First, his contour lines were defined with reference to arbitrary limits, not the limits suggested by the distribution of the data. Secondly, he has made an intuitive blend of the tensile strength of the leather and stretch of the leather at 225 kg. per square centimeter. Thus, his contour

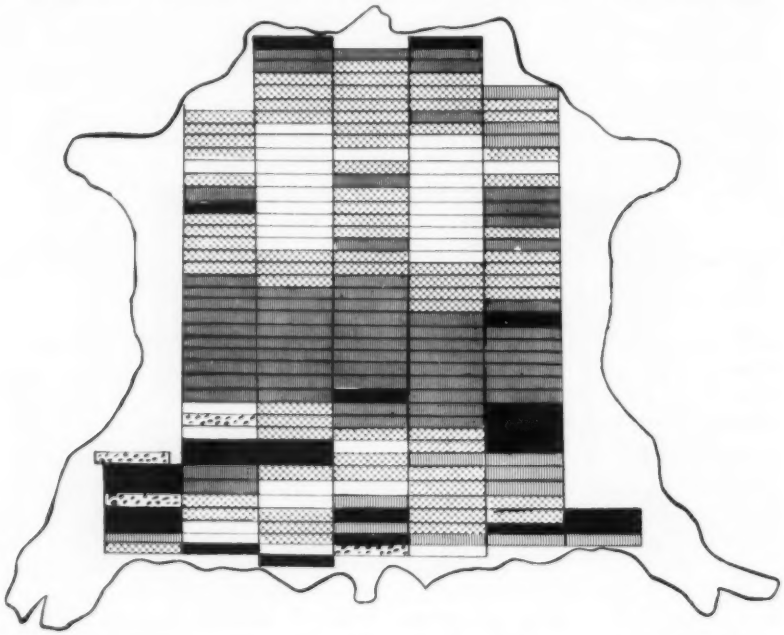

FIGURE 8.—Contour diagram for tensile strength of vegetable-tanned calfskin. Specimens perpendicular to backbone.

map does not reflect a discrete physical measurement of the characteristics of the leather.

It is unfortunate that the other published work on the distribution of the tensile strength of leather does not include the original data. Since the data are not available, the contour maps which have been published cannot be examined by the methods outlined here to determine their statistical validity.

One must conclude that much more work needs to be done before much confidence can be placed in contour maps of the distribution of tensile strength of leather over the hide area. It is suggested that when this is done, the frequency distribution of the observed values be used to assign the contour lines rather than an intuitive basis. At present all that the author would conclude from Wilson's data is that the normal frequency distribution is a fair representation of the data. Since a normal distribution results from ran-

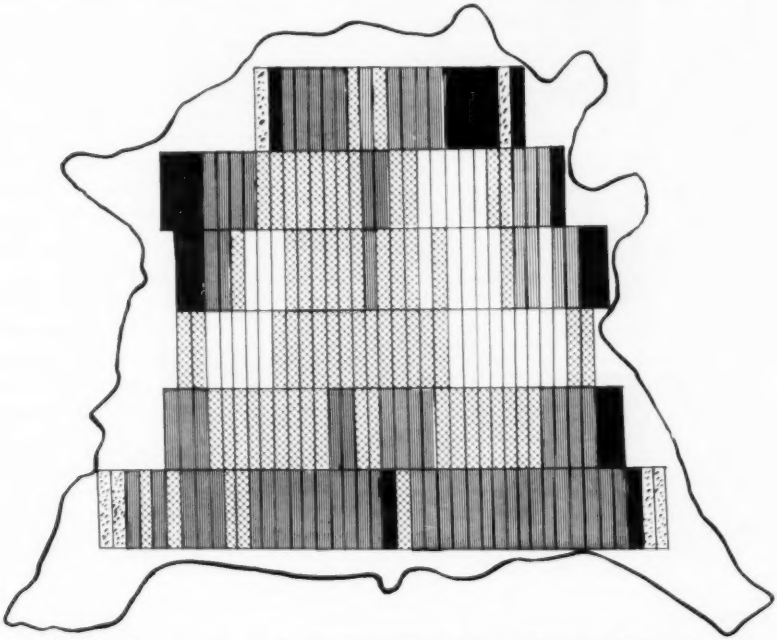

FIGURE 9.—Contour diagram for tensile strength of chrome-tanned calfskin. Specimens parallel to backbone.

dom action of many factors, each of small magnitude alone, the question is raised concerning the validity of the concept of characteristic areas over the area of the skin. While the data would seem to indicate that the weakest leather originates, as expected, in the flank areas, it is not possible on the basis of the available data to describe a single contour map which might be generally applicable.

The first draft (5, 13) of the Association's method for tensile strength included the assumption, implicit in all classical definitions, that the breaking

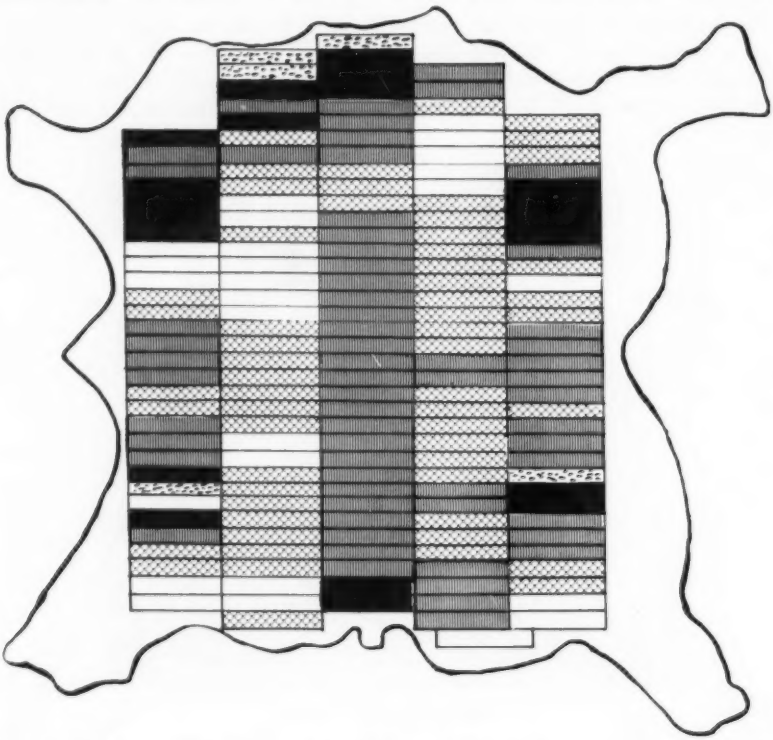

FIGURE 10.—Contour diagram for tensile strength of chrome-tanned calfskin. Specimens perpendicular to backbone.

loads should be corrected for differences in the specimen cross-sectional area. This method provided that the average width of the restricted portion of the specimen should be determined and that the thickness of the specimen should be determined in five different spots along the length of the restricted portion. Then, the thickness adjacent to the break and the average width were used to compute a specimen cross-sectional area so that the results could be expressed as pounds per square inch for each specimen. Some variation of this instruction exists in present methods. Thus, method E15 provides that the thickness and the width of the specimen shall be measured at three points in the restricted portion of the dumbbell-shaped specimen; the median of these two sets of measurements is used to compute the cross-sectional area. The Society of Leather Trades' Chemists method (41) provides that the specimen width shall be measured on both the grain and flesh side of the specimens at three points along the restricted specimen length; the thickness of these specimens is also measured at similar points along the specimen. The six width measurements and the three thickness measurements are averaged by taking their arithmetic mean, and these two averages are used to compute the specimen cross-sectional area. This instruction takes into account the fact that in heavy leathers the specimen cut by the conventional dies often has a cross-sectional area which is not rectangular. It is interesting to note, however, that the two societies do not agree upon the correct method to calculate the central tendency in their repetitive measurements of width and thickness; neither society presents any evidence to justify its particular choice.

Neither society has published evidence which justifies the classical assumption that the tensile breaking load of leather is directly dependent on the cross-sectional area of the specimen. The available literature is equally sparse in its contribution to this subject. Since it is probable that this assumption has been taken from other fields without critical evaluation, it is necessary to consider this classical assumption.

From intuitive reasons it is doubtful whether the tensile breaking load is directly dependent on the cross-sectional area of the specimen because of:

(*a*) The variable cut fiber effect, which varies as the ratio of the total thickness of the leather to the total thickness of the original hide varies.

(*b*) The variable corium-to-grain balance in different thicknesses of leather, which varies as the leather thickness is a variable proportion of the total hide thickness.

(*c*) The variable stratigraphic composition of different thicknesses of leather. Hauck and Lollar (16) have found that the specimen hide substance has a more pronounced effect on leather strength than does the leather specimen thickness with lots of commercial leather. When one considers the effect of the variable dilution of the hide substance in different strata of the leather and the effect of variable lubrication of different strata of the

leather, it seems clearly evident that the stratigraphic composition of leathers of different thicknesses should influence the strength differently.

Baumann (7) has emphasized these points recently in his thoughtful article on modern leather testing. He concludes that results should not be calculated to a uniform thickness because leather is not homogeneous in cross section, physical properties do not change in proportion to thickness, and a given leather is available only in certain thickness ranges.

The probable effect of these factors upon the relationship between the cross-sectional area of the specimen and its tensile breaking load is that the thicker specimens will yield higher breaking strength values than would be predicted by thinner specimens. Thus, a curvilinear relationship between the cross-sectional area and the tensile breaking load would result rather than the customary assumption that a linear relationship which includes the origin of the axes (i.e., zero load at zero thickness). This possibility was checked by examination of the data which were secured from the examination of 21 leathers for which average data are given in Table III.

Quenouille (32) discusses the appropriate analysis of variance technique which is applicable for the evaluation of the assumption that there is a linear relationship between the specimen cross-sectional area and the tensile breaking load. This analysis of variance described by Quenouille was applied to our data; the following results were secured:

Source of Variation	Degrees of Freedom	Mean Square	F-Ratio
Ascribable to linear effect	1	61,067	
Ascribable to nonlinear effect	19	2,408	12.0
Between leathers	21–1 = 20		
Within leathers	21(3–1) = 42	201	
Total	21x3–1 = 62		

This analysis of variance clearly indicates that a nonlinear relationship is present, since the variance ratio at the 1% level of significance for 19 and 42 degrees of freedom is approximately 2.37.

These same data have been further examined to yield the results shown in Fig. 11. The individual 63 values have been shown as small, open circles whose size is representative of the precision assignable to the individual values. The best straight line which could be fitted to the data was determined by least-squares techniques, and this line has been drawn through the scatter diagram of Fig. 11. It is noted that this line does not pass through the origin, which, of course, is predictable, since the analysis of variance indicated that a straight line could not satisfactorily represent the data.

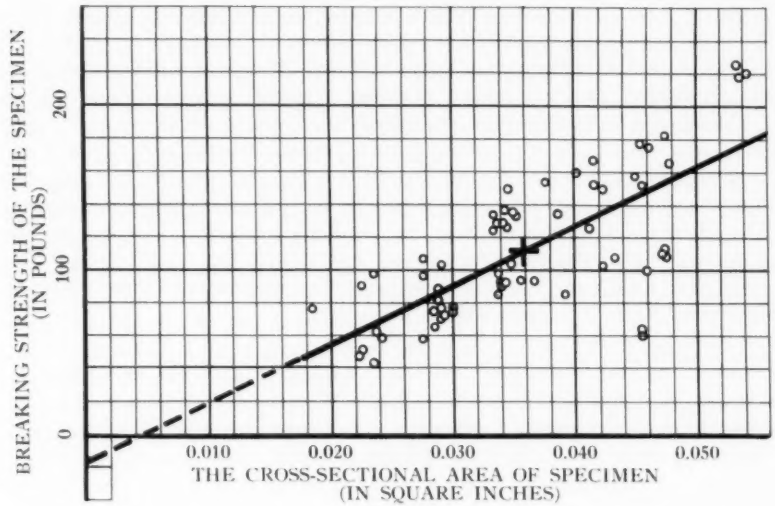

FIGURE 11.—Tensile breaking load vs. cross-sectional area of specimen. ALCA Method E15. R (correlation coefficient) = 0.728; $R^2 = 0.53$. Regression equation in pounds = 0.359 × (area × 10^4) — 16.7.

It will be recalled that the correlation coefficient (40a), a number which is 0 for a completely random scatter diagram and 1 for a direct, linear regression, may be squared to yield a measure of the interdependence of the two factors being considered. While Fig. 11 shows that the correlation coefficient for the data is +0.728, which is statistically significant, its squared value, or 53%, indicates that the interdependence of the two factors can account for only approximately one half of the variation in the tensile breaking load.

Since these leathers originated from quite dissimilar commercial sources, it is possible that the interdependence of tensile breaking load on specimen cross-sectional area might be greater from more homogeneous lots of leather. This should minimize the variation in the relative corium and grain thickness in the leather as well as the effect of leather composition on strength. It was decided that calfskin leather would offer the best possible chance to discover the possible contribution of the thickness of the specimen to its strength, since this leather is not split but is shaved to secure minor corrections in leather thickness. This would certainly minimize the large differences in the amount of corium fibers in the specimen thickness which is found in the grain splits used in side leather. Roddy and Jansing (37) have secured data in which 30 commercially tanned calfskins were examined in 6 different locations on both sides of the backbone. Thus, 360 pairs of leather thickness and

breaking load values were available for study. The sampling diagram was the same as that described by Hamel and Roddy (15) except that the pattern did not extend over as much of the area of the calfskins as it did in their work on goatskins. The 6 sampling positions occupied a block 15″ along the backbone and 18″ across it, in the central bend area of the skins. The specimens were orientated with their long dimension perpendicular to the backbone and were labeled A to F to identify the sampling position, starting with A at the shoulder end and ending with F at the kidney-area side of the block. The 12 sets of data representing the 6 different sampling positions on the 2 sides of the backbone were studied individually for the 30 skins. The correlation coefficient (40a) was the statistical parameter chosen to study these data, with these results being secured:

Sampling Location	Correlation Coefficient	
	Left Side	Right Side
A	+0.452	+0.626
B	+0.322	+0.469
C	+0.532	+0.526
D	+0.619	+0.663
E	+0.733	+0.719
F	+0.722	+0.770

All these values are large enough to indicate a statistically significant correlation; all values except the first two values on the left side attain the 1% level of significance, and these two values attain the 5% level.

To estimate the practical significance of these values it was decided to test them for their statistical equivalence, and to combine them, if equivalent, into a population estimate of the correlation coefficient. This was done by the method described by Snedecor (40a). The 12 values were found to be statistically equivalent and to yield an average correlation coefficient estimate of 0.61. When this value is squared, one sees that these data indicate that the interdependence of the breaking load on specimen thickness accounts for only 37.5% of the variation. This, of course, is even less than that secured from the data from the 21 different leathers for which the data were presented earlier. Thus, even in a homogeneous commercial lot of leather the customary assumption in the calculation of tensile strength is of doubtful value.

Data were also recently obtained on the correlation between the tensile breaking load and the specimen cross-sectional area from some experimental work on sole leather. Data were available from 8 sets of 32 determinations of tensile strength. When the techniques just described were applied to the sole leather data, it was found that the mean value of the correlation co-

efficient between specimen cross-sectional area and tensile breaking load was only +0.440. This is equivalent to a value of r^2 equal to 0.1936; this indicates that the covariation accounts for only 19.4% of the variation in load to break the specimens. Thus, again the customary assumption that the tensile breaking load is directly dependent on the specimen cross-sectional area has been shown to be of doubtful value.

Snedecor (40b) has discussed this interrelationship between data very cogently; in a summarizing paragraph, he states: "Unless there is reason to believe that the regression equation contains the origin and that the standard deviation is directly proportional to X, the ratio, Y/X, is of dubious value. It may do for rough work but careful experimental procedure deserves the more efficient statistical method."

His discussion suggests that the assumption that it is desirable to divide the tensile breaking load by the cross-sectional area might actually make the experimental work less effective. To see whether this was possible, data reported by Roddy and Jansing (36) from this Laboratory were examined. Roddy and Jansing were interested in estimating the effect of humid storage of leather on its physical properties, with data being presented for a chrome-tanned, a vegetable-tanned, and a chrome-vegetable stuffed retanned leather. They made the customary assumption of a direct, linear dependence between the tensile breaking load and the cross-sectional area, since this assumption is made both in ALCA method E15 and KK-1-311 method 2011.

Snedecor (40c) described the appropriate analysis of covariance procedure that is applicable to the analysis of the raw data without making the dubious assumptions in the Association's methods. He also described a procedure whereby the efficiency of the covariance assumption can be directly compared with an analysis of the data which does not make the assumption. In the case of the data secured by Roddy and Jansing this technique was used to compare the efficiency of analyses conducted directly on the tensile breaking load values to analyses conducted with the covariance assumption that the tensile breaking load is dependent on specimen cross-sectional area. When the techniques described by Snedecor were applied to Roddy and Jansing's data, the following results were secured:

Leather Type	Correlation Coefficient	Efficiency Ratio
Stuffed retanned leather	+0.055	0.863
Fatliquored chrome-tanned leather	+0.039	0.893
Fatliquored vegetable-tanned leather	+0.823	3.53

It is interesting to note that for the fatliquored chrome-tanned leather and for the stuffed chrome-vegetable retanned leather, which are very common

types of shoe upper leather, the covariance assumption is entirely unjustified. The assumption *reduced* the efficiency of Roddy and Jansing's experiment in these two cases. However, on the less common vegetable-tanned shoe upper leather the covariance assumption did increase the experimental efficiency, since the ratio exceeds 1, reflecting the high correlation coefficient found on this leather.

This conclusion that the efficiency of Roddy and Jansing's work was reduced by the assumption that the specimen thickness and breaking load are linearly related does not imply that their conclusions were incorrect. Actually their experiment had sufficient size to substantiate their conclusions even with the inefficient assumption which is contained in the Association's method. The lowered efficiency merely would require more testing to make a close decision; since the correlation coefficient between thickness and breaking load is positive and generally statistically significant, it is not likely that the use of the inefficient statistic would cause erroneous conclusions to be drawn.

The confidence which one may have in data is, of course, related to their precision. If the assumption that the tensile breaking load is directly dependent upon the cross-sectional area of the specimens were correct, the data expressed in pounds per square inch should be much more precise than those expressed in pounds of breaking load. The data secured by Roddy and Jansing (36) were also examined to secure the following data:

Tannage	Data Corrected for Area		Data Not Corrected	
	Standard Deviation lb./sq. in.	Coefficient of Variation %	Standard Deviation lb.	Coefficient of Variation %
Retan	364	12.6	16.7	12.2
Chrome	562	19.7	25.3	21.1
Vegetable	627	16.1	39.1	21.3

The standard deviation values were calculated from analyses of variance and are estimates of the inherent errors in the measurement. The coefficients of variation are the percent which these standard deviations are of the average strength of the leathers tested. It is noted that the main result of the assumption that the tensile breaking load has a direct, linear correlation with the specimen cross-sectional area is to give one bigger numbers to manipulate. For the vegetable leather, for which it was noted earlier that a gain in efficiency does result from the covariance assumption, a small but insignificant increase in the coefficient of variation results if the data are not corrected. On the other two leathers no gain was made as a result of all of the tedious calculation of the individual specimen data to pounds per square inch.

In view of these results it is suggested that the Association should consider a revision of method E15 which would not make the erroneous assumption of a linear, direct dependence of tensile breaking load on the specimen cross-sectional area. This suggestion would be consistent with the conclusions drawn by Baumann (7). The following recommendations are made:

1. Research workers should take advantage of the analysis of covariance techniques to make whatever statistical correction is indicated from the data themselves.

2. The American Leather Chemists Association should make two specific modifications of method E15. These are:

a. The measurement of the width of the constricted portion of the specimen should be dropped and the specimen width taken as the width of the cutting die.

b. The thickness of the constricted portion should be estimated by method E4. This value should be treated as an independent parameter which describes the leather.

For intercomparisons of leathers of equivalent commercial thicknesses the breaking load could be used without correction for specimen cross-sectional area. If leathers of widely different thickness are to be compared, the average thickness of all of the specimens and the cutting die width should be used to calculate an effective average cross-sectional area. The average breaking load and this average cross-sectional area could then be used to calculate an average tensile strength which would have utility for rough intercomparisons of leathers of quite different thicknesses. If these recommendations are followed, much of the tedium of the usual tensile strength test will be eliminated; the time thus gained could be used to much better advantage by conducting additional tests so that the confidence to be attached to the results may be increased.

The review by Lollar (21) in 1940 has cited several other factors concerned with the method of testing which influence the results that are obtained. Factors that have been considered include the dimensions of the dumbbell-shaped specimen, the amount which the skin or hide has been shaved or split prior to cutting of the leather specimen, the effect of the ambient relative humidity on the leather moisture content, and the rate of extension of the specimen. These factors have their individual independent effects, and many of them interact with each other to influence the strength value that will be attained.

The amount of shaving or splitting of the stock to attain the leather thickness, of course, is the origin of the cut-fiber effect which was mentioned earlier. Furthermore, the shaving or splitting also results in a variable amount of grain layer of the skin or hide in the leather specimen. It is a common ex-

perience that a leather of a given thickness which has been cut from a heavier hide, resulting in an abnormally low level of corium fibers in the leather, will be weaker than the leather split to thickness from a hide whose thickness was not so great. That is, weak leather can result when the hide has been oversplit in an attempt to secure the commercially desired leather weight.

The tensile strength test is, of course, arbitrary in that the specimen dimensions bear little relationship to any use condition leather may meet. If the specimen is too narrow, the effect of the cut fibers on the edges of the specimen is overemphasized, so that an erroneously low strength would result. On the other hand, excessively wide samples require more leather area for testing, so that leather variation becomes a more significant factor. An extreme variant of this type of test is the breaking strength test, method E16, where a 3″ x 6″ specimen is used. Since the specimen is not dumbbell-shaped, specimens may break in the jaws, where the effect of clamping contact may influence the results. Method E15 and its several variant precursors have used specimens whose restricted width was 0.5″ and have spaced the clamping jaws so that 4″ to 5″ of unclamped leather lies between the jaws. Hence, jaw breaks are not anticipated, and the occasional specimen which does fail in locations outside the restricted portion of the specimen can be eliminated from the sample.

The moisture content of the leather, influenced to some extent by leather composition and by the ambient relative humidity, affects the tensile strength of leather both directly and indirectly. First, the moisture in the leather serves as a lubricant to modify the leather strength. Secondly, the moisture in the leather influences the leather surface area; hence, the cross-sectional area of the specimen would be influenced so that a small indirect effect would be noted when the results are computed as pounds per square inch. The original method of the Association as described by Emley (13) employed a conditioning atmosphere of 65% relative humidity; the Association's present method, E1, requires 50% relative humidity. This lower value will maintain slightly lower moisture contents in most leathers; however, the effect on the physical properties of the leather has been found to be small. Mann (23) presented some data to the physical testing committee which showed that many physical properties of leather are changed less than 1% when the same leathers are tested after storage in the old, or 65% R.H., and in the new, or 50% R.H., conditions.

Hobbs (17) presented data on the effect of the speed of the elongating jaw upon the tensile strength of vegetable-tanned steerhide leather. The relationship was found to exhibit an increase in strength with an increase in jaw speed; however, between 6″ and 12″ per minute for the jaw speed, there was an insignificant increase in the strength. These results indicated that minor variations in machine speed would have the least effect in this speed

range; this observation is reflected in the present specification in Method E15 which calls for a speed of 10″ per minute.

Hobbs secured his results on a horizontal, pendulum-type machine, using a specimen which had a 2″ restricted portion. Emley emphasized in the discussion of his paper that the capacity of the machine influences the loading of the specimen with this type of machine. Furthermore, the rate of jaw travel becomes significant only when it is transmitted into specimen extension. Thus, the relative amount of the restricted portion of the specimen and of the exposed dumbbell portion of the specimen influences the results. This interaction between the extension of the two portions of the specimen is the cause of the fact that percent elongation estimated from the specimen stress-strain curve and from separation of gauge marks on the specimen will not agree. Method E15 uses a speed of 10″ per minute with a restricted specimen length of 2.5″. Thus, the theoretical maximum elongation rate is 400% per minute; since specimens either 6″ or 6.75″ long are permitted, the exposed length of dumbbell-specimen length can vary from 4″ to 4.75″, and the actual elongation rate of the restricted specimen length may vary but will be less than the theoretical maximum. Also, as newer types of tensile testers are employed, the variety in rates of specimen extension which are possible becomes even greater. It would be interesting to see whether the observations made by Hobbs could be confirmed on other leathers, particularly lighter-weight leathers such as calf or kid.

UTILITY OF TENSILE STRENGTH MEASUREMENTS

Tensile strength measurement of leather has received a reasonable amount of use throughout the three-quarters of a century since its development. A major use of the method today arises from the fact that many federal specifications include a tensile strength requirement. Furthermore, research and development personnel in the leather industry have continued to find it valuable as a tool to estimate the quality of leather.

Table III presents some typical data taken from federal specifications for leather which include a specification limit on the tensile strength of the leather. These specifications do not indicate the logical basis upon which the limits were set, but experience with these and other specifications for leather suggests that they were established intuitively, based upon knowledge of the characteristics of commercial leathers. These limits have not been based upon the known frequency distribution of the properties of the commercial leathers of the particular class. They represent an average value for the strength of leather specimens taken in specified sampling locations, sometimes with the specimens oriented both parallel and perpendicular to the backbone direction. Since failure of leather to render satisfactory service is a characteristic of the lower, weaker tail of the frequency distribution, specification limits which

TABLE III

SPECIFICATION FOR TENSILE STRENGTH OF LEATHER

Description of Leather	Specification		Specification Limits		
	Number	Date	Tensile Strength lb. per sq. in.	Elongation % at lb./sq. in.	
Harness, vegetable-tanned	KK-L-00171d	12/16/54	Not less than 4000	Not more than 20	2500
Hydraulic, mineral-tanned	KK-L-00177c	1/31/55	Not less than 3000	No specification	
Hydraulic, vegetable-tanned	KK-L-00181c	1/29/54	Not less than 3500	Not more than 30	2500
Belting, vegetable-tanned	KK-B-00201c	1/13/55	Not less than 3800	Not more than 15	2500
Lace, mineral-tanned	KK-L-00201c	12/21/54	Not less than 3000	Not more than 20	1500
Strap, vegetable-tanned	KK-L-271d	6/17/54			
		2 to 3 oz.	2000 minimum	Not more than 20	1800
		4 to 5 oz.	2400 minimum	Not more than 20	1800
		6 oz. and over	3000 minimum	Not more than 20	2000

permitted a minimum fraction of the individual test specimens to fall below a certain limit which had been based on the known frequency distribution for the particular leather would be more realistic. Such information would be much more informative about the value of the lot of leather than the average value which is calculated today to represent the lot.

Use of the tensile strength method in tanneries sometimes results from the desire of the particular tannery to assure that their production continues to exhibit a strength level which either is dictated by the desire to sell the leather against the specifications which have been mentioned or on the basis of an intuitive assumption that leather whose strength falls below a given limit is undesirable. Hence, some tannery use of the method as a quality control technique has occurred.

This paper has already noted that leather chemists often use the tensile strength method to detect changes in the quality of the leather as a result of some modification of the tannery process or as a result of exposure of the leather to some form of deterioration. Thus, Roddy, Jacobs, and Jansing (35) used the method as one of several physical testing methods to evaluate the influence of drying methods on the properties of chrome vegetable-retanned leather. O'Flaherty and Marshall (30) used it as one of several physical test methods to evaluate the effect of a long-time oak-hemlock tannage in comparison to a present-day sole leather tannage. Pomeroy (31) studied the influence of small quantities of oil on the tensile strength of vegetable-tanned hides. Maeser and Dion (22) studied the effect of splitting on the tensile properties of leather. Hauck and Lollar (16b) have recorded the tensile strength of cured hides. Roddy and Jansing's study of the effect of aging of chrome, vegetable, and chrome vegetable-retanned leathers at 100% relative humidity and at 20°, 30°, and 40°C. furnished data which have been referred to earlier in this paper. These several citations to the use of the tensile strength method by leather chemists are not intended to be exhaustive but rather to be indicative of the variety of applications which have been made of the method.

LIMITATIONS OF THE TENSILE STRENGTH METHOD

The determination of the tensile strength must be regarded as an empirical procedure. We have noted earlier that, in general, tensile strength determinations do not yield a parameter which defines the salient, dominant domains of the fundamental structure of the material being tested. In addition, the very nature of the test itself contributes to this empirical characteristic of the method.

First, it must be noted that the use of the dumbbell-shaped specimen, which defines a specific test area which is removed from the clamping area on the specimen, imposed an artificial application of the tensile loading upon the leather. A tensile failure of leather in service which involves a $\frac{1}{2}''$ specimen

width is very uncommon, since the actual stressed units are wider than ½" in all cases except certain lace leathers.

A second limitation of the tensile strength test arises from the failure of the ultimate strength of the leather to be directly proportional to the specimen cross-sectional area prior to rupture. We have noted earlier the problems which this assumption can cause.

A number of additional specifications for the strength of leather contain a tensile breaking strength test, but a rectangular specimen is used instead of the dumbbell-shaped specimen. This test method is based upon ALCA method E16 or its equivalent, KK-1-311a method 2031. This test method involves a more complex application of tensile forces, since one jaw of the two clamps which hold the leather during the test is smaller than the other jaw, so that the leather specimen tends to form a trough during the extension. Clamp effects are, therefore, more prominent in results from this test method. The method is used particularly on leathers whose thickness is not readily measured. Thus, federal specification KK-L-154a for bag and case leather, KK-L-00167a for oil-tanned chamois leather, and KK-L-00291d for upholstery leather use this alternate tensile testing method. The Upholstery Leather Group's "Industry Specifications and Standards" includes a similar procedure. Since the method is for leathers whose thickness is difficult to estimate with precision, the tensile breaking loads are recorded in pounds; thus, this method avoids the questionable assumption of a linear relationship between thickness and breaking strength. However, some of the specifications include different minimum breaking loads for different thicknesses of commercial leathers. These limits seem to have been established from experience; it would be desirable to establish these limits upon the basis of known population distributions of the strength of these leathers of different commercial thicknesses.

We have noted earlier that the nominal rate of extension in the restricted area is 400% per minute. This rate of specimen extension originates from the specific crosshead speed and specimen length which were selected. The crosshead speed was selected, as we have noted, to minimize the effect of variation in speed of specimen extension on the tensile strength results. This was particularly significant when tensile strength determinations were made more frequently with hand-driven machines whose speed could not be controlled precisely. However, it must be remembered that the response characteristics of a material to tensile elongation are not independent of the rate of elongation. Ballou and Roetling (6) have studied this question for textile fibers and have noted that most conventional tensile testing equipment produces extension rates that are two or three decades below the estimates made for the extension velocities in actual use of the fibers. A similar study of the tensile testing of leather should be made; it may be that the criteria which were used to select the standard size of specimen and speed of crosshead travel

when the Association method was being established are not the proper criteria to make the results most informative about the service characteristics of the tested leather.

We have noted earlier the question which arises with reference to the choice of the preferred orientation of the test specimen with reference to the backbone, with conventional orientations placing the specimen either parallel or perpendicular to the backbone. While certain particular uses of leather, such as welting or belting leather, might establish a preferred specimen orientation for testing this leather, other uses of leather, such as shoe upper leathers or garment leathers, do not establish any preferred specimen orientation. Hence, the Mullen burst test often is suggested as being valuable because it does permit the leather to exhibit its natural response instead of imposing an artificial response direction by the test method.

THE RELATIONSHIP OF THE TENSILE STRENGTH METHOD TO OTHER TEST METHODS

The Association has several test methods in the E section by which the physical properties of leather are tested by the application of tension to the specimen. We have noted the relationship which exists between the principles of method E15 for the determination of tensile strength and method E16 for the determination of breaking strength. The Mullen bursting strength test has been noted to be a test in which tensile forces are applied especially to the grain of the leather and in which the leather can fail in any orientation of the line of failure with respect to the backbone line of the hide. However, the Association also uses several methods for the determination of the tearing strength of leather, and it has been suggested that these several methods might be measuring essentially the same characteristics of the leather.

Roddy and Lollar (38) studied this question of chrome vegetable-retanned leather. The technique used to show the extent of interrelationship of the several test methods was the calculation of the statistical correlation coefficient. The authors found that the tensile strength showed a weighted average correlation coefficient of +0.64 with tongue tear, of +0.65 with two-hole stitch tear, and of +0.85 with small-ball burst strength. Teramura and Roddy (4) extended this work; they found the following correlation coefficients for tensile strength and

Notch tear strength	+0.785
Tongue tear strength	+0.534
Stitch tear strength	+0.475
Mullen grain crack	+0.594
Mullen burst strength	+0.662

Ramanathan and Subbalakshmi (33) have recently published a short article on the interrelationships between the physical properties of chrome-

retanned upper leather. They report a small, positive correlation between tensile strength and elongation at break, which they note is opposite to that found in single-fiber work. They conclude that the mechanism of tensile strength break and failure in stitch tear tests are different. They found that tensile strength correlated to a marked degree with grain crack, and it is suggested that the tensile strength test would be a useful test for upper leathers.

These data have been secured on retan leather where the variability in leather resulting from the splitting of the leather to secure commercial shoe upper leather weights would influence the results. Roddy and Jansing (37) have secured some data on calfskin leather which have been discussed before; this leather was shaved to make minor corrections in the leather weight, so that the results from this leather might be expected to exhibit maximum uniformity. Considering the question raised by Ramanathan and Subbalakshmi (33) on the relationship between the tensile breaking load and the stretch of the leather at break, it may be noted that Roddy and Jansing's data did support a correlation coefficient between the two parameters of the stress-strain curve of −0.11. However, the magnitude of this correlation coefficient is so small that it must be regarded as 0, even though 360 stress-strain curves were analyzed to secure the data. One must, therefore, conclude that the load at which the tensile strength specimen fails is not proved to be directly or inversely related to the extension at which the leather fails. This implies that these may be two independent parameters which describe the stress-strain response characteristics of the leather.

Roddy and Jansing's data also provide estimates of the correlation coefficients between tensile breaking load and

Stitch tear strength in pounds	+0.569
Tongue tear strength in pounds	+0.607
Small-ball burst strength in pounds	+0.648

It may be noted that these correlation coefficients are of the same order of magnitude as those reported for chrome vegetable-retanned leather.

Some idea of the practical significance of these correlation coefficients may be demonstrated, since the square of the correlation coefficient may be used to estimate the degree of interrelationship between the correlated variates. The square of 0.707 is only 0.50; it is, therefore, obvious that very high correlation coefficients are required before much significance should be attached to the interrelationship. Another insight into the value to be assigned to these correlation coefficients between the different test methods may be found in the fact that the bilateral symmetry correlation for tensile breaking load in pounds was only +0.677 in Roddy and Jansing's data on the calfskin leather. The correlation coefficient between adjacent specimens

in these same 360 measurements of tensile strength was +0.854 for tensile breaking load in pounds. This value is considerably higher than the bilateral symmetry correlation and the between-test method correlations given earlier, yet it indicates an interrelation of only $(0.854)^2$, or 0.73. Therefore, one should not expect different test methods to give exceptionally good correlation coefficients. Except for the lack of correlation between tensile breaking load and elongation at break, the various tear and burst strength tests have given significant direct correlations with tensile strength. Hence, we might conclude that the various test methods do give similar quality ratings to leather but that differences in the inherent properties of the leather in different specimens and differences in the exact principles concerned in the several test methods cause the different methods to give different relative ratings to the several specimens. While the several methods often give results which agree in direction, they do not generally agree exactly in their assessment of leather quality. For this reason the several methods have continued to be used, with the selection of the particular method being based on the particular service demands made on the particular leather whose quality is to be rated. Thus, stitch tear strength and Mullen grain crack are quite frequently used for shoe upper leathers, while tensile strength determinations are more frequently made on belting leather.

PRECISION AND ACCURACY OF TENSILE STRENGTH RESULTS

Since we have noted that the tensile strength test is an empirical method whose results are influenced by so many factors, it is not logical to expect that the accuracy, or exact conformity to truth, of the results will be absolute. However, the precision of the results, or their degree of variation, is important, since the precision of the results determines the amount of testing that must be done so that decisions of reasonable validity concerning the test results can be made. Hence, the Joint Committee on Leather has correctly decided that the methods descriptions should include an estimate of the precision of the results which might be representative of the method. The American Leather Chemists Association has long required a somewhat vague proof of the precision of its methods in the statement that "An official method is one adopted as such after having been in use for at least one year as a provisional method, and that has been proved to give concordant results in the hands of different operators."

Beek (8) has stated that "the probable error in the measurement of the tensile strength of heavy leather is estimated to be 265 lb/in^2, with a probable error of about 2%. The effects of differences between hides and between locations on the same hide were eliminated from the calculation of the estimate." Section 17 of the "Official Methods of Analysis" of the Society of Leather Trades' Chemists (41) states in footnote (iii):

"The following standard deviations of tensile strength may be taken as typical of various types of leather; the unit in each instance being 1 lb. per square inch:—
For specimens cut from one location in a single skin, and cut in the same direction:—
calfskins 700; goatskins 500
For specimens cut from the same location and in the same direction from nominally similar hides or skins, that is, ones processed in the same batch at one tannery:—
calfskins 1600; curried belting leather 600."

The American Leather Chemists Association has never included a precision estimate in its description of methods, despite the importance of such estimates in any use of the method. The efficiency of use of the methods would be improved if three different precision estimates were available:

1. The variation between adjacent specimens in a single location in a hide. This precision estimate might be considered to be the inherent error of the method when applied to leather.

2. The contribution of the variation from position to position within the skin or hide to the results.

3. The contribution of the variation from skin to skin or hide to hide when sampled in the same within-side location.

It may be noted that Beek (8) has presented a value for the first of these estimates of precision when the tensile strength test is applied to heavy leather. The Society of Leather Trades' Chemists' method (4) has included values for the first and/or third precision estimates for three different leather types. However, these estimates have been presented in units of pounds per square inch. Since this method of calculation must reflect the error of three different physical measurements (thickness, width, and pounds to break), and since data given earlier have challenged the validity of the assumption that the tensile breaking load is directly proportional to the specimen cross-sectional area, it was decided that data on the precision estimates of the several parameters of the tensile strength test might be desirable.

The data secured on the stress-strain response properties of the 21 different leathers which were discussed earlier in this article made it possible to determine estimates of the precision of the several parameters of the tensile strength test method. The data obtained were examined by statistical techniques to secure the desired precision estimates.

Method E15 provides that the width and the thickness of the specimens shall be measured at three points along the narrow section of the specimen. The width is measured to the nearest 0.02" while the thickness is measured to the nearest 0.001". The median value of the three thicknesses and of the three width measurements is used to calculate the specimen cross-sectional area for use in the calculation of the tensile strength results. The ALCA method does not provide any instructions for the determination of the width of heavy leather specimens, where the cross-sectional area of the specimen

is often trapezoidal rather than rectangular in shape. Section 17 of the methods of the Society of Leather Trades' Chemists provides that the width on the grain side and on the flesh side shall be measured at three locations along the narrow portion of the specimen, and that the six readings shall be arithmetically averaged to estimate the specimen width. Neither of the methods provides any estimates of the errors of these measurements nor considers the question of the dependence of the tensile breaking load on the cross-sectional area of the specimen.

To provide information in order to estimate the inherent error in the measurement of the width, thickness, and specimen cross-sectional area of adjacent tensile strength specimens, the 126 specimens taken from the 21 different shoe upper leathers described earlier were each measured according to the instructions in method E15. The thickness of the specimens was measured to the nearest thousandths of an inch (mils) in accordance with method E4. To insure sufficient precision in the estimation of the specimen width, a vernier micrometer reading to 0.01 cm. of the vernier was used. Since method E15 requires that width measurements be made to the nearest 0.02" or 0.051 cm., this use of the vernier micrometer insured that our data would be as accurate as required by method E15. The cross-sectional area of each specimen was calculated as directed in method E15, in which the median thickness and the median width are used. Since in each case the six replicate samples from each of the 21 different leathers were taken from an area 7.5" square, statistical estimates of error made from these data should provide a good estimate of the inherent error of measurement. This is particularly true when it is realized that the six replicate measurements on each leather were concentrated in the center of the 7.5" area.

Statistical analyses of these data provided the following error estimates on these leathers:

	Width cm.	Thickness mils	Cross-sectional Area square inches
Average	1.228	74.5	0.0360
Standard deviation	0.014	2.4	0.00123
Coefficient of variation, %	1.1	3.2	3.4

These data show that the determination of specimen thickness establishes the effective precision of the measurement of the cross-sectional area of the specimens. The precision of the width measurement, whose standard deviation of a single measurement estimated from adjacent test specimens is 0.014 cm., is equivalent to the precision of the vernier micrometer used. Furthermore, the average width of the test specimens is the same as the interior width of the cutting die which was used.

Data were also available from which it was possible to make similar estimates of the precision of measurement of the specimen width, thickness, and cross-sectional area on sole leather specimens. A total of 128 pairs of adjacent specimens were subjected to the tensile strength determination as directed in method E15. From the dimension data secured on these pairs of specimens the following information was calculated:

	Width cm.	Thickness mils	Cross-sectional Area square inches
Average	1.076	232.2	0.0983
Standard deviation	0.0021	7.18	0.003
Coefficient of variation, %	0.20	3.1	3.1

The average width of these sole leather specimens is less than the average width of the side leather specimens. A different die was used to cut these two sets of specimens; the die used on the sole leather was about 0.01 cm. (0.025″) narrower than the one used to cut the side leathers. Furthermore, the sole leather specimens were trapezoidal; the width measurements were made across the specimen at the midpoint for thickness. This dimension was less than the grain width of the specimen, which was more nearly equivalent to the die width.

While the width of the firmer sole leather specimens could be measured somewhat more accurately than the width of the softer side leather specimens (which tended to compress slightly when the micrometer was applied to the specimens), it will be noted that the precision of the measurement of the cross-sectional area of the specimens is the same for each type of leather. The absolute value of the standard deviation of a single determination of the thickness of the leather was greater on sole leather than on the side leather specimens, when adjacent specimens were used in each case to furnish these estimates. However, since the average value was also greater on sole leather, it will be seen that the coefficient of variation is the same in each case. Furthermore, the precision of the determination of the cross-sectional area has obviously been established by the determination of thickness, since the coefficients of variation for the area units are the same as for the thickness units.

The ALCA methods of analysis include two methods, E17 and E17A, for the determination of the elongation of leather during a tensile strength determination. The official method (E17) employs bench marks placed upon the specimen; the separation of these bench marks during the tensile strength test is followed with dividers. The alternate, nonofficial method (E17A) uses data taken from the stress-strain curve of the specimen as recorded autographically by the tensile tester. These two were compared on each of the triple replicate sets of specimens taken from the 21 side leathers discussed

earlier and on the 128 pairs of adjacent test specimens of sole leather. As expected, these two methods did not give identical results, since the alternate method E17A applies the extension so that a portion of ends of the dumbbell specimen, as well as the full, restricted portion of the specimen, is extended. Hence, the alternate method would be expected to give a lower level of percent extension to break than would the official method. The precision of the official method was, as expected, lower since the bench marks are difficult to follow, and error in reading of only 0.1″ in following the separation of the bench marks is equivalent to a 5% error in the elongation measurement.

The magnitude of these effects was found to be:

	Method E17	Method E17A
Side leather		
Average elongation, % at break	52.7	38.5
Standard deviation	11.4	5.39
Coefficient of variation, %	21.7	14.0
Sole leather		
Average elongation, % at break	24.6	21.4
Standard deviation	2.31	1.83
Coefficient of variation, %	9.4	8.5

These data were secured upon the Instron tensile tester, so that the data for method E17A were recorded with a twofold magnification of the extension of the specimen made. Thus, the extension of the specimens could be read directly from the chart in percent extension when a 5″ jaw spacing was used. This minimized the work in the determination of percent elongation and also minimized the chance of erroneous results being recorded.

Federal Specification KK-L-311 and the Methods of Analysis of the Society of Leather Trades' Chemists (41) both include an elongation method based upon principles similar to those of Official Method E17. Neither of these specifications includes an estimate of the precision to be expected in the results. It must be realized that the elongation method is an empirical method, so that the absolute magnitude of the percent elongation secured on the specimens cannot be identical to the elongation which a gross piece of the leather might undergo prior to rupture. Since the alternate method E17A is more precise and less laborious to use than method E17, it is recommended that consideration be given to replacing E17 by E17A. Those tensile instruments not equipped with a recorder may easily be equipped with a tape and indicator device which will enable the operator to follow jaw separation visually so that an equivalent elongation figure may be determined even on the simpler tensile testers.

This paper has emphasized in an earlier section the failure of the customary assumption that the tensile breaking load is directly dependent upon the cross-sectional area of the specimen and has made certain recommendations for an alternate method of handling this question. It was decided that it would be desirable to present some additional evidence on the question of the precision which would be anticipated in data for the tensile strength of leather. The examination of the 21 triplicate sets of tensile strength specimens taken from 21 different side leathers and the data from the 128 pairs of replicates of sole leather specimens which have furnished the precision estimates for cross-sectional area and for elongation measurements were also examined to furnish precision estimates for the tensile breaking load, expressed both in pounds to rupture the specimens and in pounds per square inch.

The data thus secured were:

	Results Given in Pounds	Results Given in Pounds per Square Inch
Side leather		
Average value	112.4	3102
Standard deviation	14.19	356.5
Coefficient of variation, %	12.6	11.5
Sole leather		
Average value	328.1	3372
Standard deviation	29.04	297.3
Coefficient of variation, %	8.85	8.81

It will be evident that the expression of the data in units of pounds per square inch has not produced a significant improvement in the precision of the results. While the absolute magnitude of the numbers is, of course, larger when the data are expressed in units of pounds per square inch instead of pounds, the above data on the coefficient of variation show that the precision of the data has not been improved by the latter method of expression. This is not surprising when it is realized that the degree of covariation is relatively low, as is indicated by the data on correlation coefficients:

	Correlation Coefficient r	Degree of Covariation r^2
Side leather	+0.728	0.530
Sole leather	+0.440	0.194

These results, of course, merely re-emphasize the conclusion given earlier, which suggests that the customary practice of calculating each individual set

of data secured from a single specimen in terms of pounds per square inch, as is required in item 5 of method E15, is unnecessary. If the calculation of the results on each individual specimen were valid, the coefficient of variation for the data expressed in pounds per square inch should be significantly reduced by this calculation. This is obviously not true.

The introductory paragraphs of this section noted that Beek (8) reported that the probable error of a single measurement of the tensile strength of heavy leather is estimated to be 265 lb/in^2. If the distribution is normal, the probable error is related to the standard error by the identity (11):

$$\text{Probable error} = 0.67449 \times \text{standard deviation.}$$

The two estimates of precision given here are consistent with the estimate by Beek, although somewhat lower in magnitude. Since different experimental details were followed and different tensile testers were used by different operators, these small differences are not considered significant.

The suggestion has been made in this paper that either the work to break the leather or the toughness index of the leather might be a valuable method of expression of the results from a tensile strength test, since these two characteristics include both the elongation of the leather and the load required to cause elongation in a single expression. Data were secured on both the 21 different sets of triplicate specimens of side leather and the 128 pairs of adjacent sole leather specimens. First, the amount of correlation between the tensile breaking load and the elongation at break as measured by the recorder was determined:

	Correlation Coefficient r	Coefficient of Covariation r^2
Side leather	+0.3488	0.1217
Sole leather	+0.2138	0.0457

While the correlation coefficient is significant for both these leathers, the coefficient of covariation indicates that the dependence of the two factors on each other does not suggest a very great practical significance to the interdependence.

The precision of the determination of toughness index was also calculated by examination of the individual data for toughness index secured on adjacent specimens of sole leather and of side leather, with the following results:

Side leather

Average toughness index	22.27
Standard deviation	4.86
Coefficient of variation, %	21.8

Sole leather

Average toughness index	35.40
Standard deviation	5.17
Coefficient of variation, %	14.6

It will be noted that the coefficients of variations for toughness index are not as low as those recorded earlier for the tensile breaking load and elongation to break on the same two leathers. Since the two parameters of the stress-strain curve have been found to have a fairly low correlation, and since the toughness index or product of the two would reflect the errors made in both individual determinations, it is not surprising that the toughness index has a larger coefficient of variation.

CONCLUSIONS

A critical review has been made of the tensile strength test as applied to leather with particular reference to the significance and precision of results secured with the method. Conclusions follow:

(*a*) The use of parameters which describe the entire stress-strain response curve of the leather specimens should be considered as a supplement to the current practice which places the emphasis on the terminal point of the response curve. For this purpose data are presented which describe a method for the estimation of the work to break the specimen, which is obtained from the total area under the stress-strain curve. The toughness index of the leather specimen is also discussed as a parameter which reflects both the breaking load and the elongation at break, which is related to the work to break and may give similar responses to differences in leather quality.

(*b*) The details of the method of the determination of the tensile strength of leather which requires the cross-sectional area of each specimen to be calculated in the determination of tensile strength has been shown to be inefficient. The dependence of the tensile breaking load on cross-sectional area is shown to be curvilinear rather than linear as is assumed in the approved method of expression of the data. It is suggested that the width of the leather specimen be taken as the die width used to prepare the specimen and that the thickness be considered a separate characteristic of the specimen. Then for any given lot of leather, the average thickness, the die width, and the average tensile breaking load could be used to calculate a tensile strength value for the lot, expressed in the customary units of pounds per square inch. This method would yield a more effective, practical comparison of different lots of leather. Where research workers wish to make more precise allowance for any dependence between leather specimen thickness and breaking load, it is recommended that the analysis of covariance technique be used for the purpose.

(*c*) The factors which influence the actual values of tensile breaking load which will be secured, such as the location of the sample and the conditions of the testing as well as the influence of tannery processing and environmental effects involved in the use of leather, have been discussed. The practical use of the method in specification testing, quality control work, and research studies has demonstrated that the test method does measure a quality indicator of leather; other test methods in the general area of tension testing have been found to give positively correlated results. However, differences in the response of the several methods to the inherent properties of the methods, as well as differences in the error contributions in the several methods, prevent them from giving identical quality rating to different leathers. Hence, practical use of the different methods of tension testing still involves selection of the particular method which seems to be the most directly concerned in each particular case.

(*d*) Data have been presented on the precision of certain parameters of the stress-strain response curve of leather. It has been found that expression of the tensile strength in pounds per square inch does not significantly improve the precision of the results in comparison to expression of the results in terms of tensile breaking load in pounds. This re-emphasizes the conclusion drawn that the individual calculation of the tensile strength in pounds per square inch for each specimen is not efficient.

(*e*) The official method of the determination of elongation to break which involves the estimation of the separation of bench marks during the tensile strength test by the use of calipers is found to give less precise results than the use of the data secured from the stress-strain response curves of the leather specimens. Since the elongation is an empirical method, the small difference in the magnitude of the elongation values from the two methods is not of practical importance. It is, therefore, recommended that the present official method E17 be replaced by its unofficial alternate method, E17A.

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DISCUSSION

DR. ELL DEE COMPTON (Eagle Ottawa Leather Company): In such work I think that some of us, or many of us, sometimes become intoxicated with figures and ignore the relation of a particular test to service. After all, in the use of leather or in the selling of it, it is the way the leather performs in service that is important and not the results we get in a laboratory.

Work of the type discussed in the paper on studies of significance of test methods is illustrated by the work of a number of men of this Association; the following come quickly to mind: Lollar, Kanagy, Maeser, Mann, and Stubbings.

I like the suggestion, with the supporting evidence, of cutting down the calculations involved in tensile strength by using the width of the die and the average thickness. I think that this would be a useful change in procedure.

The toughness index appeals because it is related, somewhat loosely perhaps, to the area under the stress-strain curve.

Now, Dr. Lollar, a question: Since there is a rough, or loose, inverse relationship between stretch and breaking load, particularly in consideration of orientation of samples—say, perpendicular and parallel to the backbone—do you feel that the use of toughness index might iron out some of the differences noted and be a more useful tool for evaluation of leather?

DR. LOLLAR: It has been my observation, in the limited opportunity that I have had to use this method so far, that at least the ratio of the magnitude of change in toughness index to the inherent error in toughness index is greater, and therefore that the sensitivity of the test is likely to be greater than that of the independent load and elongation data.

DR. COMPTON: Instinctively, I don't like test to failure, because we are interested in how a product is going to perform at stresses below that point. In your work on the samples before they were tested to failure, I believe that you worked them up to two-thirds of the breaking work. Would it be well in calculating the toughness index to say arbitrarily that you would take the elongation and the load at two-thirds its breaking load to calculate the toughness index? Would you have any gain there?

DR. LOLLAR: Mr. Roddy has shown that beyond a certain uncrimping region in the early portion of the stress-strain curve there is a fairly linear relationship; and therefore any point taken further down on the curve would be relative to the end point.

I can see one real gain from the suggestion that you have just made, and that is, that the reproducibility of the early portions of the stress-strain curve is better than the end point, and therefore that the precision of the toughness index at a load less than that required to rupture the specimen should be better than the precision of the toughness index at rupture. Therefore, your suggestion is valuable.

DR. COMPTON: Dr. Kanagy used a parameter somewhat similar to the toughness index, where he used the product of tensile strength and elongation. Does Dr. Kanagy have any comments on this or any other part of the paper?

DR. KANAGY: I believe I suggested in one paper that I thought it might be a good idea to calculate the tensile strength on the basis of hide substance, since strength is more nearly a function of amount of hide rather than cross-sectional area. This, of course, would have theoretical significance only. Now the toughness index, as I understand it, is a product of the load and the stretch.

DR. LOLLAR: One-half that, as Smith actually defined it.

DR. KANAGY: In some work that we did we averaged the product of the stretch and of the strength in two different directions (perpendicular and parallel to the backbone), and it came out as a constant, equal in both directions. This indicates, of course, that if the load is high, the stretch will be low; and if the load is very low, the stretch will be greater. You will tend to reach a constant value for the product. So I believe that if you would base it on a toughness index, you would probably get a closer check or closer value independent of the direction in which you make the determinations on the hide.

DR. CHARLES W. MANN (Quartermaster Research and Development Center, Natick, Massachusetts): I have one question regarding the test method. Do I understand correctly that the specimens that were tested after two-thirds load were new specimens?

DR. LOLLAR: The data reported were reported on a total of 126 specimens, 63 of which, selected in an alternate random fashion to be representative of the total, were directly broken. The other 63 were mechanically stressed through the five stressing cycles, relaxed for one month, and then broken. But they had retained the elongation shown in the table and called permanent deformation.

DR. MANN: In calculating the area under the curve, was the area taken from the original dimensions or from the new dimensions with the permanent set after the relaxation?

DR. LOLLAR: The area under the curve is not related to the cross-sectional area of the specimens. The area is the area of the actual graphical representation of the stress-strain curve and is not related to the specimen other than the fact that it was secured from the specimen. It is square inches of paper, you might as well say, in the particular magnification that I chose to use on the instrument to represent these results. If you want to know where the numbers came from, I used a twofold magnification of the stress axis and a 200-lb. scale for the load axis.

DR. MANN: I understand that. But you take a specimen and apply two-thirds of the ultimate breaking load and, say, it stretches one inch, and then you allow it to age one month. When you put the specimen back in the testing machine, do you start your test with a 4″ span?

DR. LOLLAR: The method specifies a jaw-spacing which will leave but a little length of the specimen extending outside the clamp. In this work, we actually used 5″ in both cases—not 4″. That is before and after extension.

DR. MANN: It seems to me that an explanation for the type results you are getting here is: In the first place, a higher load would be expected on the basis of a different rate of loading the specimen. A specimen prestressed at two-thirds of its ultimate breaking load has a part of the so-called kinking taken out; therefore, when the load is applied, it is applied more rapidly to the unkinked specimen than to the initial specimen. Furthermore, in calculating the area under the curve, if you start again at zero extension with the prestressed specimen, the initial kinking is out of the curve. Therefore, your extension will be less; and with the same breaking load, of course, the area under the curve is reduced proportionately.

DR. LOLLAR: Your analysis may be valid. The one point I would make is that the percentage of work to break which is represented by the unkinking region on these leathers was, in general, a small proportion of the total; therefore, that effect is a minimal effect.

MR. WHITMORE: I think I have the same idea in mind as Dr. Mann. If those charts are used to infer a deterioration or damage to the specimen, I think it is a fallacy because if you measure that by your work-to-break formula, your stretch is one of the denominators of your work-to-break formula and you have eliminated part of your stretch by the preliminary stress, and therefore you would automatically get less work to break.

DR. LOLLAR: No inference was needed that the specimens were damaged. It was obvious. My choice was of a parameter which would reflect the damage which the load had failed to do.

MR. WHITMORE: It looks to me as if the parameter you used was reflecting the fact that some of the stretch has been eliminated and also some of the work done by the preliminary stressing. Part of the work was already done.

DR. LOLLAR: The samples were obviously, as would be said in the metal-working or in other industries, embrittled, as the stress-strain curves did reflect. I was choosing parameters that would reflect that—the decrease in toughness index, the decrease in work hardening. Leather has the same properties as many other materials have, and I merely wished to choose a parameter that would give me a realistic result instead of giving me something that said that the obviously damaged leathers were better leathers.

MR. WHITMORE: But it looks as if the parameter had a built-in result there, cue to the method of calculation regardless of any damage to the leather. There was no damage indicated.

DR. LOLLAR: These stress-strain curves are merely reporting responses of the leather which reflect the condition of the leather as I knew it to be—it is built-in. It was selected to be built-in because the leather was obviously damaged and I needed something . . . .

MR. WHITMORE: You are picking a parameter that will show . . . .

DR. LOLLAR: That will show the quality of the leather.

DR. MERRILL: If it was obvious that the leather was damaged, what was the need of making any measurements at all? From the standpoint of a telephone lineman or a window-washer—which is more significant—the toughness index or actual pounds to break?

DR. LOLLAR: The toughness index, the amount of energy which that belt can absorb, is the thing that determines his safety. How fast he moves his weight is the thing that establishes whether the belt breaks or not, and not the fact that it is a 200-lb. man, necessarily. The fact that he moves a 200-lb. weight against the belt at a certain rate establishes whether the belt fails or not, and whether he falls or not.

DR. MERRILL: It is obvious that in service the weight is not applied in the manner that it is applied in the Instron tester or any other tester, where there is a gradual and continuous increase in tension. This eliminates completely what you might call the "jerk "factor.

MIETH MAESER (United Shoe Machinery Corporation): Have you ever tried to relate your factor to the burst test which has some of the components of both stretch and strength in it? Both factors work together in this test to give the results finally obtained.

DR. LOLLAR: I am in the process of studying the interrelationship of these variables with reference to the burst test. I am using a factor which has been suggested by work done by the upholstery research group—the so-called spherical stretch, and the equivalent spherical toughness index, which is the spherical increase in area times the load to break. I think that a burst test would be more valuable than the tensile test for many of our uses of leather, particularly in the shoe industry.

As America approaches the decade of the 1960's, it can take reasonable satisfaction in its past scientific and technological accomplishments. Thoughtful men now see another role for science and technology—a new and creative role that is still only dimly grasped. Science is the one common language understood the world over. It is dedicated to the discovery of truth and to scrutinizing every new finding and hypothesis without fear or prejudice. In science new beliefs and principles win out over earlier ones because they have behind them the irresistible force of logic and consistency. By exchanging scientific viewpoints and working on common scientific problems—as exemplified so admirably in the International Geophysical Year and the two international Conferences on the Peaceful Uses of Atomic Energy—men of all nations may be drawn closer together. The endless frontiers of science, now stretching to the stars, can provide rich opportunities for men to seek a common understanding of the natural forces which all men must obey and which govern the world in which all men must live together.

—*Strengthening American Science*, A Report of the President's Science Advisory Committee, Dr. J. R. Killian, Jr., *Chairman*. Dec., 1958.

ALCA NEWS

Proceedings, Reports, Notices, and News

of the

AMERICAN LEATHER CHEMISTS ASSOCIATION

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PRIZE PAPER

Dr. Lee P. Witnauer of the Eastern Regional Research Laboratory in Philadelphia has been awarded the $1000 prize for his paper entitled "Dynamic Electrical Behavior of Untanned Hide Containing Sorbed Water." Dr. Witnauer will read his prize paper at the biennial meeting of the International Union of Leather Chemists' Societies in Munich, September, 1959.

EMPLOYMENT NOTICES

WANTED—Graduate chemist for opening in laboratory of Midwest tannery. Training or experience in leather chemistry desirable but not essential. Send replies to Box E-506, c/o Secretary, American Leather Chemists Association, University of Cincinnati, Cincinnati 21, Ohio.

SALES AND SERVICE REPRESENTATIVE WANTED by established leather finish manufacturer. Permanent position with excellent opportunity. Must have tannery background, be able to demonstrate in finish department, and be willing to travel principally east of Chicago. Sales or service experience preferred. Send full details and references. Information will be held in confidence. Our staff knows of this advertisement. Address replies to Box M-508, c/o Secretary, American Leather Chemists Association, University of Cincinnati, Cincinnati 21, Ohio.

INDIAN HIDES AND SKINS IMPROVEMENT SOCIETY

A communication has been received from Dr. S. K. Barat, Executive Secretary, Central Leather Research Institute, Adyar, Madras-20, India. He requests that we publicize the Institute's aims and objectives in our *Journal*. We are glad to cooperate with our associates in India in this way.

At a symposium held in Madras in March, 1957, the delegates expressed great concern at the progressively deteriorating situation regarding the quality of hides and skins produced in India. Since hides and skins play an important part in the national economy, it was felt that the time had come to re-examine the whole question of the improvement of raw hides and skins, with immediate attention focused on the eradication of the damage caused by warbles, beetles, and ticks.

As a result of the deliberations of a special committee, the Indian Hides and Skins Improvement Society was inaugurated on February 16, 1959. Its aims and objectives are as follows:

1. To disseminate knowledge relating to and plan for the improvement and maintenance of the quality of raw hides and skins available in India, mainly of the hides and skins derived from cattle, goat, and sheep and of such other skins as are utilized in the tanning industry.

2. To achieve the above object by spreading information suggesting methods for the improvement of the species of livestock and for the promotion of better health among animals by eradicating diseases, pests, etc.

3. To further achieve the above object, disseminating information regarding means and methods for:

(*a*) the collection of old and useless animals and founding suitable animal homes at central places in the country,

(*b*) improvement of the methods of collection and storage, and of the technique of flaying hides and skins from slaughtered and fallen animals,

(*c*) improvement of the technique of curing hides and skins, and

(*d*) proper utilization of the carcass by-products of fallen animals, etc.

4. To educate the villagers in modern methods of obtaining the best value for the hides, skins, and offal from the carcasses, which education will ultimately offer them an incentive to take better care of animals while they are alive.

5. To arrange meetings, discussions, lectures, demonstrations, seminars, and symposia relating to the collection, collation, and dissemination of knowledge, modern tools and techniques in the trade and for other purposes intended for the improvement of hides and skins.

6. To keep in regular touch with individuals and associations both in India and abroad connected with raw hides and skins and the improvement thereof.

7. To collect information from members of different regions in India covering such matters as methods of improving the species of livestock; methods of dealing with parasites which damage hides and skins; ways and means of avoiding damage to the horns, hoofs, etc.; slaughterhouse methods, flaying techniques, methods of curing, preservatives, handling, conditioning, grading, transporting, etc., of hides and skins; and technical data relating to modern tools and techniques.

8. To act as consultant and guide for passing on to individuals, members, and public and private organizations, information about improvement of hides and skins and to suggest means and methods to improve such of those techniques that would help the growth and improvement of the raw hides and skins industry.

9. To cooperate with and coordinate the activities of allied organizations at governmental and non-governmental levels for the better achievement of the above objects.

10. And to do all such things and take all such measures incidental or conducive to the attainment of the above objects or any of them with a view to benefit the general economy of our country.

AUDIT REPORT

ARTHUR W. HOLMES
CERTIFIED PUBLIC ACCOUNTANT
CINCINNATI, OHIO

February 26, 1959

THE AMERICAN LEATHER CHEMISTS ASSOCIATION, INC.
THE UNIVERSITY OF CINCINNATI
CINCINNATI, OHIO

GENTLEMEN:

In accordance with the request of Dr. Fred O'Flaherty, Secretary-Treasurer, we have examined the balance sheet of the American Leather Chemists Association, Incorporated, as of December 31, 1958, and the related statements of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

The report of the examination is presented herewith, together with the following exhibits:

EXHIBIT I: Balance sheet at December 31, 1958, and comparison with December 31, 1957.

EXHIBIT II: Statement of income for the year ended December 31, 1958, and comparison with the year ended December 31, 1957.

EXHIBIT III: Statement of surplus for the year ended December 31, 1958, and comparison with the year ended December 31, 1957.

The commercial account balance on deposit with the Central Trust Company was confirmed independently and was reconciled with the cash account balance of the Association.

Accounts receivable were not circularized; this procedure was considered unnecessary in view of the small balance of each account, and in view of the fact that of the total accounts receivable of $1,373.03 at December 31, 1958, approximately seventy-five per cent of the total was collected in January, 1959. By other auditing procedures, we have satisfied ourselves of the accuracy, validity, and collectibility of the accounts.

The investment securities, were confirmed by Dr. Fred O'Flaherty. In addition, we examined the bonds in details. All bonds are in the safe deposit box at the Central Trust Company.

In July, 1958, United States Treasury bonds, Series G, costing $5,000.00 were sold for $5,000.00. United States Treasury 2.25% bonds of the 1959-1962 series were purchased at a cost of $10,000.00, and the United States Treasury 2.5% bonds of the 1967-1972 series, par $5,000.00, were purchased at a cost of $4,712.50.

Accumulated interest on the Series F bonds has been added to the original cost of the $5,000.00 par value of Series F bonds owned at December 31, 1958.

At December 31, 1958, the total accumulated value of the Series F bonds is $4,645.00, of which $945.00 represents accumulated interest. In the year 1958, all bond investments earned interest of $1,361.46.

Dues received in advance totaling $214.50, advertising received in advance totaling $57.75 and subscriptions received in advance totaling $3,046.42 were verified in detail and were reconciled with the controlling accounts.

Net income for the year ended December 31, 1958, was $2,056.38, compared with $1,168.98 for the year ended December 31, 1957, or an increase of $887.40. The causes of the increased net income are analyzed in Exhibit II. In the year 1958, revenues increased $1,029.46, and expenses increased $142.06. The net income is satisfactory.

In our opinion the accompanying balance sheet and related statements of income and surplus present fairly the financial position of the American Leather Chemists Association, Incorporated, at December 31, 1958, and the results of its operations for the year then ended, in conformity with generally accepted principles of accounting, applied on a basis consistent with that of the preceding year.

Respectfully submitted,

ARTHUR W. HOLMES,
Certified Public Accountant

EXHIBIT I

BALANCE SHEET AT DECEMBER 31, 1958 AND COMPARISON WITH DECEMBER 31, 1957

	December 31, 1958	December 31, 1957	Increase or Decrease* 1958 over 1957
ASSETS			
Current Assets			
Cash on hand	$ 3.11	$ 1.60	$ 1.51
Cash in bank	7,658.61	16,289.76	8,631.15*
Accrued interest on Treasury bonds	–0–	537.50	537.50*
Accts. rec., advertisers	1,260.03	1,714.51	454.48*
Accts. rec., reprints	76.00	112.50	36.50*
Accts. rec., Directory	37.00	–0–	37.00
Total Current Assets	$ 9,034.75	$18,655.87	$ 9,621.12*
Investments			
U. S. Sav. Bonds, Series F (cost $3,700 plus $945 accrued interest at December 31, 1958)	$ 4,645.00	$ 4,500.00	$ 145.00
U. S. Sav. Bonds, 2.5%; 1972–1957, at cost	33,207.50	28,495.00	4,712.50
U. S. Treas. Bonds, 2.5%; 1968–1963, at cost	8,842.50	8,842.50	–0–
U. S. Treas. Bonds, 2.5%; Series G, due July 1, 1958; at cost	–0–	5,000.00	5,000.00*
U. S. Treas. Bonds, 2.25%, 1962–1959, at cost	10,000.00	–0–	10,000.00
Total Investments	$56,695.00	$46,837.50	$ 9,857.50
Total Assets	$65,729.75	$65,493.37	$ 236.38
LIABILITIES AND CAPITAL			
Current Liabilities			
Accounts payable	$ 112.26	$ 1,917.01	$ 1,804.75*
Income tax withheld	237.40	237.40	–0–
City tax withheld	14.99	14.99	–0–
Total Current Liabilities	$ 364.65	$ 2,169.40	$ 1,804.75*
Deferred Credits to Income			
Advertising received in advance	$ 57.75	$ 24.00	$ 33.75
Dues received in advance	214.50	195.50	19.00
Subscriptions received in advance	3,046.42	3,114.42	68.00*
Total Deferred Credits	$ 3,318.67	$ 3,333.92	$ 15.25*
Total Liabilities	$ 3,683.32	$ 5,503.32	$ 1,820.00*
Capital			
Earned surplus (Exhibit III)	$60,046.43	$58,990.05	$ 1,056.38
Reserve for foreign meeting	2,000.00	1,000.00	1,000.00
Total Capital	$62,046.43	$59,990.05	$ 2,056.38
Total Liabilities and Capital	$65,729.75	$65,493.37	$ 236.38

EXHIBIT II

STATEMENT OF INCOME
FOR THE YEARS ENDED DECEMBER 31, 1958 AND DECEMBER 31, 1957

	December 31, 1958	December 31, 1957	Increase or Decrease* 1958 over 1957
Revenues, General			
Dues, *Journal* subscription included	$11,377.00	$11,592.00	$ 215.00*
By-Laws and Methods booklets	64.20	73.00	8.80*
Directory	789.66	770.66	19.00
Interest income	1,361.46	1,205.00	156.46
Total General Revenues	$13,592.32	$13,640.66	$ 48.34*
Revenues, *Journal*			
Advertising	$13,676.15	$12,326.68	$ 1,349.47
Subscriptions	6,158.76	6,223.39	64.63*
Journal sales	886.41	555.52	330.89
Reprints	1,142.29	1,299.97	157.68*
Dues, ISLTC	563.50	943.75	380.25*
Total *Journal* Revenues	$22,427.11	$21,349.31	$ 1,077.80
Total Revenues	$36,019.43	$34,989.97	$ 1,029.46
Expenses, General			
Salary of Secretary's personnel	$ 4,600.00	$ 4,600.00	–0–
Office operating expense	1,197.33	1,087.34	109.99
Uncollectible accounts expense	430.00	323.00	107.00
Directory expense	962.68	894.67	68.01
By-Laws and Methods	613.80	–0–	613.80
Annual meeting expense	483.20	275.16	208.04
Council meeting expense	117.83	158.90	41.07*
Auditing	200.00	200.00	–0–
Winheim Memorial Award	–0–	100.00	100.00*
ISLTC, union dues	119.74	119.25	.49
Total General Expenses	$ 8,724.58	$ 7,758.32	$ 966.26
Expenses, *Journal*			
Printing	$19,103.45	$19,921.15	$ 817.70*
Managing editor, compensation	2,500.00	2,500.00	–0–
Managing editor, expense	223.01	191.05	31.96
Editor-in-chief, compensation	600.00	600.00	–0–
Editor-in-chief, expense	194.67	199.64	4.97*
Miscellaneous expense	60.78	–0–	60.78
Storage	350.00	350.00	–0–
Insurance	62.00	62.00	–0–
Copyright registrations	48.00	48.00	–0–
Reprints	1,282.41	1,667.43	385.02*
Exchange charges	4.55	5.35	.80*
Translations and abstracts	439.47	294.19	145.28
Committee expense	107.69	97.80	9.89

EXHIBIT II (*Continued*)

	December 31, 1958	December 31, 1957	Increase or Decrease* 1958 over 1957
Advertising written off	111.00	–0–	111.00
Advertising discounts allowed	151.44	126.06	25.38
Total *Journal* Expenses	$25,238.47	$26,062.67	$ 824.20*
Total Expenses	$33,963.05	$33,820.99	$ 142.06
Net Income	$ 2,056.38	$ 1,168.98	$ 887.40
Net income distributed:			
General	$ 4,867.74	$ 5,882.34	$ 1,014.60*
Journal	(2,811.36)	(4,713.36)	1,902.00*
Total	$ 2,056.38	$ 1,168.98	$ 887.40

EXHIBIT III

STATEMENT OF SURPLUS

FOR THE YEARS ENDED DECEMBER 31, 1958 AND DECEMBER 31, 1957

	Year Ended December 31, 1958	Year Ended December 31, 1957	Increase or Decrease* 1958 over 1957
Balance, January 1	$58,990.05	$58,821.07	$ 168.98
Add Net Income			
General	4,867.74	5,882.34	1,014.60*
	$63,857.79	$64,703.41	$ 845.62*
Deduct Net Loss			
Journal	2,811.36	4,713.36	1,902.00*
	$61,046.43	$59,990.05	$ 1,056.38
Deduct			
Allocation to reserve for foreign meetings	1,000.00	1,000.00	–0–
Balance, December 31	$60,046.43	$58,990.05	$ 1,056.38

SIXTH CONGRESS OF THE INTERNATIONAL UNION OF LEATHER CHEMISTS SOCIETIES

Munich, Germany, September 7–11, 1959

Saturday, Sept. 5—Sunday, Sept. 6
Sessions of the International Commissions and the Executive Committee

Monday, Sept. 7

Morning

9:30 to 12 — Festive opening session in the Herkulessaal of the Royal Palace (Residence) with welcome addresses, and with Harvey Memorial Lecture given by Prof. D. Burton, Leeds, England

Afternoon

2 to 6 — At Kleine Kongresshalle, Ausstellungspark (Exhibition Grounds)

Symposium: "Constitution and Chemical Properties of Vegetable Tannins." (*Intended for a small number of interested participants*)

Prof. Dr. K. Freudenberg, Heidelberg, Germany: "Proanthocyanidines and Catechins as Precursors of Tannins"

T. White, Harpenden, England, *The Forestal Land, Timber and Railways Comp. Ltd. Central Laboratories*: "Biogenesis of Condensed Tannins"

D. G. Roux, Grahamstown, South Africa, *Leather Industries Research Institute*: "The Chemistry and Biochemistry of Some Commercially Important Condensed Tannins"

D. E. Hathway, Egham, England, *British Leather Manufacturers' Research Association*: "The Enzymic Oxidation in Polyphenols and the Origin of Tannin in Forest Trees"

Prof. Dr. W. Grassmann, Munich: "On Polyoxystilbenes, a New Class of Condensable Tannins"

Prof. Dr. O. Th. Schmidt, Heidelberg, Germany: Subject to be announced later

Prof. Dr. C. Mentzer, Paris: "Recent Progress in the Chemistry of the Chestnut Wood Found in France"

Evening

7:30 — Reception at the Seehaus am Kleinhesseloher See, beside a charming lake in the English Gardens

Tuesday, Sept. 8

Morning

9 to 12:30 — Lectures at Kleine Kongresshalle, Ausstellungspark

Focal Point: "Collagen"

Main Lecture: Prof. Dr. F. O. Schmitt, Cambridge, Mass.: "The Tropocollagen Macromolecule"

Dr. K. Kuhn, Darmstadt, Germany: "On the Origin of the Various Cross-Striation Patterns of Collagen"

A. G. Ward, London, *The British Gelatine and Glue Research*: "Structural Relationship between Collagen and Gelatine"

Afternoon

1:30 to 3 First meeting of delegates

3 to 6 Reading of general papers

Evening Evening free. We suggest: Richard Strauss Festive Concert at the Herkulessaal of the Royal Palace (Residence), or play at the Kammerspiele of the Munich Schauspielhaus.

Wednesday, Sept. 9

Morning

9 to 12:30 Lectures at Kleine Kongresshalle, Ausstellungspark

Focal Point: "Aldehyde and Quinone Tanning"

Proposed program: Lectures and discussions on theoretical and practical aspects of mono- and dialdehydes as tanning agents in leather manufacturing

Afternoon

2 to 5 Reading of general papers

Evening

7:30 Bavarian Evening at the Festsaal of the Munich Hofbräuhaus, with stage show

Thursday, Sept. 10

Morning

9 to 12 Lectures at Kleine Kongresshalle, Ausstellungspark
Reading of general papers

Afternoon

2 o'clock Excursion to Herrenchiemsee Castle with concert in the candle-illuminated castle; dinner arranged for entire party
Return to Munich about 11 p.m.

Friday, Sept. 11

Morning

8:30 to 12:30 Lectures at Kleine Kongresshalle, Ausstellungspark

Focal Point: "Vegetable Tanning—in Particular, Combination Tanning with Chrome"

Dr.-Ing. H. Herfeld, Reutlingen, Germany: "Problems of Vegetable Tanning Technology"

G. S. Shuttleworth, Grahamstown, South Africa, *Leather Industries Research Institute*: "Modern Methods

and Problems of Chrome plus Vegetable Combination Tannages"

H. G. Wollenberg, Beverley, England, *R. Hodgson & Sons, Ltd.*: "Application of Rate-of-Tannage Studies to the Tanning of Heavy Leathers"

Afternoon

2 to 3 Second meeting of delegates

3 to 5:30 Reading of general papers and final session

Evening

7:30 Soiree at the Hotel Bayerischer Hof, Promenadeplatz
End of Congress

Saturday, Sept. 12

Morning

9 to 11:30 Meeting of the members of the German Society for Leather Chemistry and Technology (V.G.C.T.)

11:30 Weisswurst Lunch (Bavarian sausage specialty) of the German Society for Leather Chemistry and Technology (Members of other Associations are welcome to attend)

LADIES' PROGRAM

An extensive program for the ladies has also been prepared.

GENERAL INFORMATION

General Charges.—The general charge for participants in the Congress is Deutsche Marks 50.00; for accompanying ladies, Deutsche Marks 5.00. The respective amounts, as well as any charges made for the individual items of the program, are payable to Verkehrsverein München not later than June 15, 1959.

Accounts: Postscheckkonto (Postal Cheque Account) 4758 München; or M/RE 1090, Bayerische Hypotheken- und Wechselbank, Munchen.

Registration.—Participants in the Congress are requested to fill in and return Registration Form I (red), Form II (white), and/or Form III (blue), whichever may be applicable. (*See printed notes on the forms.*) Please fill in carefully, either with a typewriter or in block letters, and return to Verkehrsverein München, am Bahnhofsplatz, Munich 2, Germany, by June 15, 1959. It is urgently requested that the exact number of participants in the various program items be stated in the registration forms, and that the above closing dates be observed, since these data are needed to ensure smooth organization of the Congress.

Accommodations.—Please direct reservations for accommodations (Form II) to Verkehrsverein München (see address above). Deadlines set for possible cancellations of rooms should be given special attention. All rooms are centrally located so that the Kleine Kongresshalle, where the sessions will be held, can be conveniently reached.

Registration of lectures.—Another separate form (Form III) is enclosed for the registration of lectures, which must not exceed 15 to 20 minutes (plus 10 minutes for discussion). Please submit the manuscript of proposed lecture(s) to Mr. George Forsyth, Secretary of I.U.L.C.S., The Highfield Tanning Co. Ltd., Runcorn, Cheshire, England, not later than June 15, 1959. Precise dimensions of slides and/or required film projector (substandard-gauge), if any, should be stated.

Congress Office.—The Congress Secretariat (headed by Mrs. B. Scheller) will be, from now to September 5, Max-Planck-Institut für Eiweiss- und Lederforschung, Schillerstrasse 46, Munich 15, Germany (telephone 595267/68). The Congress Office will be located September 6 in Verkerhsverein am Bahnhofsplatz (Munich Main Railway Station) (telephone 555881/83); after September 7: Kleine Kongresshalle Ausstellungspark (Exhibition Grounds) (telephone 557584). The Reception Office at Verkehrsverein am Bahnhofsplatz (see above) will be opened from 8 a.m. to 12 midnight on September 6 and 7.

Arrival.—Participants in the Congress will please report at the Reception Office immediately upon their arrival in Munich, where they will be issued all their papers (Congress Program, Participant's Cards, etc.).

Editor's Note: *It is suggested that those interested in attending the meeting of the International Union write promptly to the Congress Secretariat, Mrs. B. Scheller, at the above address. A program, registration blanks, and a picture map of Munich will be supplied.*

DIRECTORY CHANGES

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DECEASED

G. H. Jennings, 2568 South Shore Drive, Milwaukee, Wisconsin. Rapco Leather Company, S. Milwaukee, Wisconsin.

ABSTRACTS

Recent Developments in the Field of Leather Oiling. E. Quendt. *Das Leder*, **9**, 222–29 (1958).—The value of a fat for oiling leather cannot be judged from its chemical composition; practical tests are required. An enormous amount of work was done on synthetic fats during World War II, but little of these products is now used. Mineral oils with a wide range of viscosities are available. They hinder spue formation and increase the stability of sulfated-oil emulsions so that oils with a lower degree of sulfation can be used. They will not migrate if their viscosity is high enough and if they comprise not over one-third of the mixture. They will loosen nitrocellulose but not casein or plastic finishes. A wide variety of Derminols can be made (*JALCA*, **46**, 483 [1951]), but they are too expensive to conquer the market; only small amounts are used in mixtures. Light stability is one of the oldest unsolved leather problems. Fat has usually been blamed for yellowing, but recent work (in progress and to be published later) shows this is only partly true. White, Cr-tanned leather did not turn yellow regardless of the type of

fat used. Retan leathers all yellowed, and unoiled leather changed most. There were differences in oils: unsaturated oils were most subject to yellowing. By treating unsaturated oils with peroxide to form epoxides, products are formed that are absolutely resistant to yellowing; however, they are too costly for general use. Esters and ethers of higher alkanediols with higher-molecular-saturated fatty acids are light-stable. Saving labor by combining the tanning and fatliquoring operations has been attempted. The first fatliquors for this use were made from products formed by heating polyethylene oxide and natural or synthetic triglycerides. They precipitate vegetable tannin and are now used only for velour or other leathers where no other oiling method can be used. Cationic fatliquors for velour leather have been developed, but they lower the leather strength. They consist of an unsulfonated oil emulsified with oleic acid and a triethanolamine ester. Sulfated oils in Cr tanning liquors form Cr soaps and so lose their emulsifying power. By reacting the carboxyl groups of such oils with ethanolamine, free acid that is present causes formation of a peptide link and leaves the hydroxyl group of the ethanolamine free to esterify with the acid. The resulting product is quite stable to salts, acids, and heavy metal ions and may be used in small amounts during Cr tanning. Sulfited oils which contain true sulfo acids instead of sulfated are stable and are not hydrolyzed by the acid in the chrome liquor as are sulfated oils. Water-soluble Cr soaps, such as du Pont's Quilon, are too expensive to be used, except in limited amounts. Leathers dried by pasting require more oil than those dried in air, and the leather surface must have enough oil so that the paste does not penetrate the leather but not so much as to prevent adhesion to the plate. Increasing the proportion of unsulfonated oil in conventional mixtures did not give satisfactory results. A 2-bath fatliquoring process is much used. The first bath consists of the usual mixture of 2/3 sulfonated and 1/3 unsulfonated oil and the second bath a mixture to oil the surface of the leather. A fatliquor made of unsulfonated oil and a mixture of ethylene oxide polymers contains both small and very large emulsion particles so that penetration and surface oiling are both attained. Recently fatliquors have been developed that are mixtures of anionic, cationic, and nonionic products. The anionic and cationic oils mutually precipitate but are emulsified by an excess of sulfated oil. Such oil cannot be used for Cr retan leather, but Cr leather can be retanned after oiling by this method. Processes for oiling in organic solvents have been developed in America. I.D.C.

The Formation of a Highly Subdivided Cross-banding of Collagen after Tanning with Phosphotungstic Acid and Basic Chromium Salt Solutions. K. Kühn. *Das Leder*, **9**, 217–22 (1958).—A review with 20 references. Natural unswollen collagen takes up irreversibly 500 mg. of phosphotungstic acid (PTA) per g. After the collagen structure has been loosened or swollen, the collagen will take up an additional 400 mg. of PTA that can be removed by prolonged washing with water. The good agreement between PTA takeup and basic group content of the collagen indicates that one PTA ion combines stoichiometrically with 3 basic amino acid residues. The firmly bound portion of PTA is held by the strongly basic guanido groups, and the fraction that can be washed out is held by the weakly basic ε-amino groups of lysine and hydroxylysine. Collagen preparations in which the ε-amino groups had been blocked or removed (DNP collagen, acetyl collagen, or collagen deaminized for 4 hr. at pH 4) could not be made to take up more PTA by opening the fiber structure. Guanido collagen in which 75% of the ε-amino

groups had been converted to guanido groups by reaction with O-methylurea took up an increased amount of PTA proportional to the increase in guanido groups. Deaminized collagen in which up to 70% of the guanido groups had been changed to nonbasic cyanamid groups by drastic treatment with nitrous acid, showed a proportional decrease in takeup of PTA. The greater the number of arginine groups that were removed by nitrous acid, the greater the amount of absorbed PTA that could be washed out with water. Electron microscopic investigations showed that the portion of PTA that was bound to the ε-amino group was not important for formation of highly subdivided bands. The intraperiod bands were equally sharp in acetyl collagen with 400 mg. and in guanido collagen with 750 mg. of PTA per g. of collagen. The PTA bound to guanido groups was essential for differentiation of bands; after intensive action by nitrous acid to destroy a portion of the guanido groups no subdivision of the bands was found. The basic unit of collagen is a superspiral formed of 3 peptide spirals twisted together but separated by a distance from 10 to 16 A., depending on the degree of swelling of the collagen. The dark bands contain the oppositely charged ionic side chains of the acidic and basic amino acids. The spherical, tribasic PTA ion, with a diameter of 10 A., fits well into the space between the unit spirals and combines with 3 guanido groups of 3 neighboring spirals. It thus holds the fibrils in register during preparation of specimens for electron microscopic observation. Basic Cr complexes attach to the acidic side chains of aspartic and glumatic acids. After tannage with basic Cr chloride 5 or 6 subdivisions were found per period, but with basic Cr sulfate 10 or 12 were found. Tannage with anionic Cr sulfite complexes also resulted in subdivisions (intraperiod fine structure). The amount of metal deposited in the collagen had little influence on sharpness of the bands. Equally sharp bands were found in specimens containing 400 mg. PTA per g. of collagen, in guanido collagen containing 750 mg. PTA, and in Cr-tanned fibrils containing 50 mg. of Cr. Photometric measurements, however, showed small characteristic differences in intensity of the intraperiod bands. I.D.C.

The Anatomy of the Hair Follicles. W. Montagna and E. J. Van Scott. *The Biology and Growth of Hair* (Academic Press, 1958), pp. 39–64.—A description. 33 references. **The Histochemistry of the Hair Follicle.** O. Braun-Falco. *Ibid.*, 65–87.—The location within the hair and root sheaths of inorganic substances, carbohydrates, lipids, amino acids, proteins, substances containing sulfhydril and disulfide groups, nucleic acids, various enzymes, and trichohyalin is described insofar as known. Histochemical aspects of keratinization are discussed. About 125 references. **Electron Microscopy of Keratinized Tissue.** E. H. Mercer. *Ibid.*, 91–111.—The dermal-epidermal junction is shown to consist of a single continuous membrane 200–300 A. thick, distinct from the plasma membranes of the cells of the basal layer of the epidermis and separated from them by a layer, probably cement, about 200 A. thick. The structure, growth, and differentiation of epidermis, hair, and root sheath cells are described, and the processes of keratinization in epidermis and hair are followed. 21 references. **Electron Microscopy and the Biosynthesis of Fibers.** E. H. Mercer. *Ibid.*, 113–33.—A review. 32 references. **The Chemistry of Keratinization.** A. G. Matoltsy. *Ibid.*, 135–69.—A review. 97 references. **The Nature of Hair Pigment.** T. B. Fitzpatrick, P. Brunet, and A. Kupita. *Ibid.*, 255–303.—A review. About 130 references. H.B.M.

Graphical Diagnosis of Interlaboratory Tests. Anon. *Nat. Bur. Standards Tech. News Bull.*, **43**, 16–19 (1959).—Each laboratory tests 2 similar samples of the same material. The results for each laboratory are plotted with the result for Sample A as ordinate and the result for Sample B as abscissa. A vertical median line is drawn with half the points to the left and half to the right, and a horizontal median line is drawn with half the points above and half below. If only random errors occur, there will be about the same number of points in each quadrant. In practice most of the points fall in the lower left and upper right quadrants, indicating that certain laboratories are consistently high or consistently low because of systematic procedural differences. A point close to one median but far from the intersection indicates that this laboratory got fairly correct results on one sample but not on the other, i.e., carelessness. The standard deviation, σ, can be obtained graphically. A circle of radius 2.5 σ centered on the intersection of the medians will contain about 95% of the points if there are no constant errors. Laboratories whose points fall outside the circle almost certainly are erratic or are following a deviant procedure. This procedure requires the cooperation of a large number of laboratories or else testing of more than one pair of samples by each laboratory. H.B.M.

Manufacture of Picking Band Leather by the Combination Sulfur-Oil-Vegetable Tanning Method. S. N. Bose, N. R. Sikdar, and K. T. Sirkar. *Bull. Central Leather Research Inst., Madras*, **5**, 50–56 (1958).—Buffalo hides are soaked with 3% salt and 1/16–1/4% NaOH, washed, and rounded into butts, bellies, and shoulders. Only the butts are used for picking bands. The butts are limed 4 days with 10% lime added in 2 parts on the 1st and 2nd days, and 2–2.5% Na_2S added in 4–5 parts on the 2nd, 3rd, and 4th days. After unhairing, the butts are washed, fleshed, split, scudded, washed again, and delimed completely with $(NH_4)_2SO_4$. Pickling is done overnight with 2.5–3% H_2SO_4 and 7.5–10% NaCl followed by a 24-hr. treatment with 15–20% $Na_2S_2O_3$. The butts are then horsed, hung overnight, dry-milled, shaved, and hand-stuffed with a mixture of 4–4.5% beef tallow, 4–4.5% fish oil, and 1% sulfated fish oil. The butts are milled several hours in a hot drum and then hung for 3–5 days at 42°–45°C. This stuffing and hanging at elevated temperature is repeated. The butts are wet back by milling with a wetting agent and retanned in a drum with sulfited quebracho, bleached with dilute oxalic acid, washed, set out, and oiled with pungam oil. They are then given yet a third stuffing with tallow and fish oil, hung at 40°–42°C. for a week, then aged for another week or, better, a month. Yield is 60–65% on pelt weight. H.B.M.

Rapid Tannage of Sole Leather Using Indigenous Indian Substitute for Wattle. E. C. Mathew. *Bull. Central Leather Research Inst., Madras*. **5**, 12–14 (1958).—An 18-day tanning process employing a 4:1 mixture of extract of *Pithecolobium dulce* bark and myrobalans is described. H.B.M.

Manufacture of Gold and Silver Leather. A. Ganesan. *Bull. Central Leather Research Inst., Madras*, **5**, 57–61 (1958).—A method for applying metallized acetate foils to leather (Indian patent No. 55819) is described. H.B.M.

Manufacture of White Glove and Lining Leathers Using Basic Aluminum Sulfate. R. Selvarangan, M. A. Ghani, and Y. Nayudamma. *Bull. Central Leather Research Inst., Madras*, **5**, 98–101 (1958).—Bated sheepskins are pickled with 0.75% H_2SO_4, 10% NaCl, and 0.17% $Na_2Cr_2O_7$; treated with 1.5% $Na_2S_2O_3$; tanned with 20% com. Al sulfate, 1.33% Na citrate, 1.5% Na_2SO_4, and 6.67% Na_2CO_3 all added together; and neutralized to pH 4.5 with more Na_2CO_3. After drying, setting, samming, and shaving, the skins are retanned with 1% HCHO. Skins are sorted for glove and lining after the first fatliquor. Glove leather is refatliquored, and lining leather is "stuffed" with an acrylic resin emulsion. H.B.M.

An Improved Process for the Enzymic Unhairing of Skins and Hides by Madar (*Calotropis Gigantea*) Latex for the Manufacture of Leather. S. M. Bose, W. Madhava Krishna, and B. M. Das. *Bull. Central Leather Research Inst., Madras*, **5**, 15–20 (1958).—A process previously covered by Indian Patent No. 50806 is described (see also *JALCA*, **50**, 192 [1955]). The skins are thoroughly soaked in water, and then soaked overnight with 1% lactic acid (40%) on the soaked weight of the skins, using a minimum float. Next morning they are thoroughly washed, drained, and weighed. Next, the skins are treated with 3% latex tapped from wild madar plants, 5% NaCl, and enough of a 2:1 mixture of lactic and acetic acids to bring the pH value to 5.5 in minimum float. The skins are handled periodically to ensure even unhairing. Time required for unhairing depends on the ambient temperature; at 28°–32°C. the time is 20–24 hr. The skins should be removed from the unhairing bath as soon as the hair comes off easily, to avoid putrefaction. If fine hair is left on the skins, they may be returned to the unhairing bath, after it has been diluted with an equal volume of water. The skins are then unhaired, fleshed, scudded, and washed in several changes of water. No bating is required. The skins are pickled and processed further by conventional methods. Outlines of these subsequent processes are given for glazed kid, box sides, glove, E.I kips, goat- and sheepskins, and sole leather. H.B.M.

Spectrophotometric Studies in Leather Research. X. Effect of Addition of Aluminum Chloride on the Ultraviolet Absorption Spectra of Tanning Materials. D. Ramaswamy and Y. Nayudamma. *Bull. Central Leather Research Inst., Madras*, **5**, 45–49 (1958).—Swain (*Chem. and Ind.*, **1954**, 1480) showed that the absorption maximum at 275–80 mμ, characteristic of phenolic OH groups, is shifted to 305–10 mμ by adding $AlCl_3$, if 2 OH groups are in *o*-position. This approach was used to investigate the structure of vegetable tannins. Absorption curves were obtained for tannin extracts partially purified by extraction with ethyl acetate, with and without added $AlCl_3$. The condensed tannins wattle and avaram show no shift in the absorption maximum after adding $AlCl_3$ and therefore do not contain OH groups in *o*-position. For the hydrolyzable tannins myrobalans and divi divi the maximum is shifted to 305–10 mμ, but the curves with $AlCl_3$ show slight inflections at the position of the original maxima, indicating the presence of some OH groups that are not in *o*-position. Dhawa and sumac give inflections, but no maxima at 305–10 mμ after $AlCl_3$ treatment, and the original 275–80 mμ peaks are retained. Chestnut gives only an inflection (no maximum) at 275–80 mμ before treatment, and inflections at both 275–80 and 305–10 mμ after treatment. It is pointed out that other structural factors may influence the ability of *o*-dihydroxy-groups to form stable chelates with Al. H.B.M.

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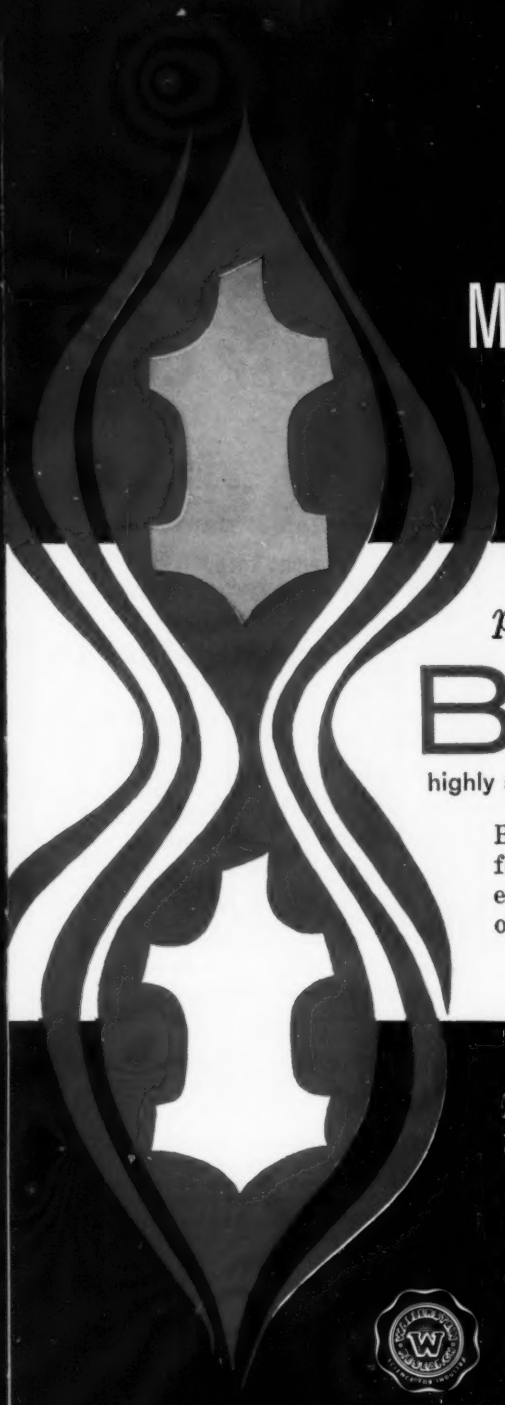

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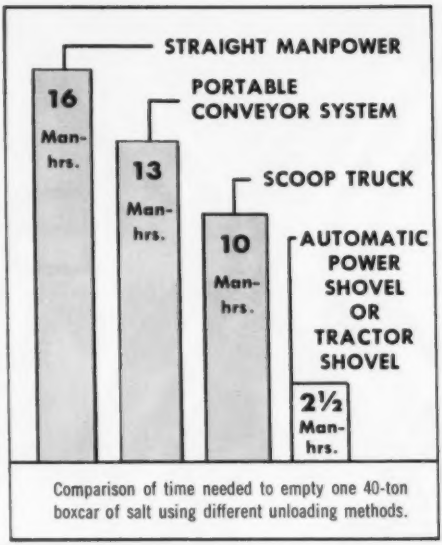
Portable Conveyor System. This is the simplest improvement over straight manpower. A power-operated belt conveyor of suitable length is placed inside the car door, and salt is then shoveled onto it. A good conveyor for most needs is generally about 16 to 18 feet long, and capable of moving salt up a 30° slope. With a conveyor, a good deal of manpower in shoveling is needed, but one 40-ton car can be unloaded in about 12 to 14 man-hours—a 19% saving in time over straight manpower.

Scoop Truck and Conveyor. A scoop truck is simply an enlarged scoop shovel with two small wheels at the bowl of the scoop. Whereas a shovel holds only about 20 lbs. of salt—a scoop truck holds 100 to 150 lbs. In operation, the scoop is pushed into the salt, tilted up, and then wheeled to the conveyor at the car door. With just one of these scoops, a worker can unload 40 tons of salt in 10 hours—and once the job is under way, there's room for two or three more men with scoops.

Automatic Power Shovel. This device consists of a large, power-operated scraper blade mounted on a cable—and is one of today's most popular devices for unloading bulk salt. The scraper is moved toward the end of the car. As soon as this motion stops, a power winch takes hold to drag the scraper toward the car door. Salt is pushed out through the door by the scraper. One man can unload a 40-ton car in 2 or 3 hours by this unique method. The installed cost of both winch and power motor is moderate.

Small Gasoline or Electric Tractor Shovel. This is somewhat similar to a fork-lift truck, but with a scoop mounted in place of the forks. One man on this type of truck can empty a 40-ton car in 2 or 3 hours—the same as power-shovel unloading. The higher cost of a tractor shovel is often justified when it can be made available for other purposes.

The best unloading method for your plant, of course, depends on the salt tonnage involved, and on the plant layout. But one of the methods just described should pay for itself—in savings on time and labor—over a relatively short period.



Comparison of time needed to empty one 40-ton boxcar of salt using different unloading methods.

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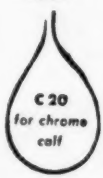

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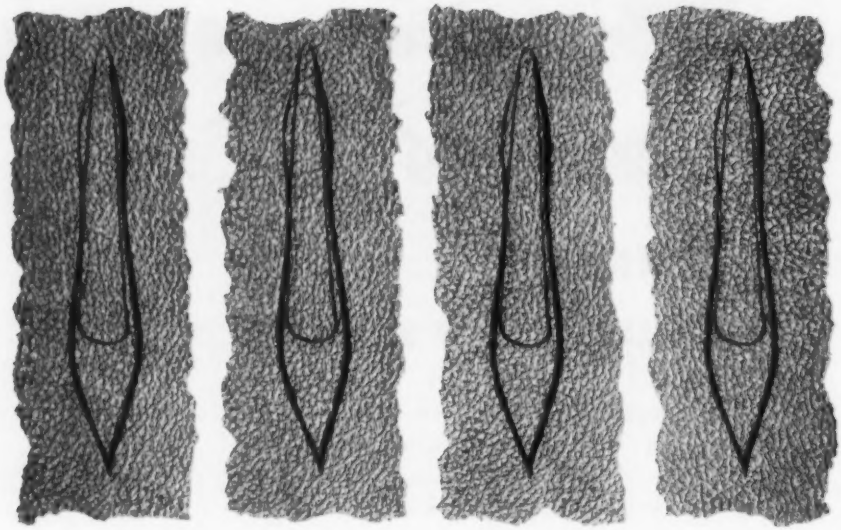

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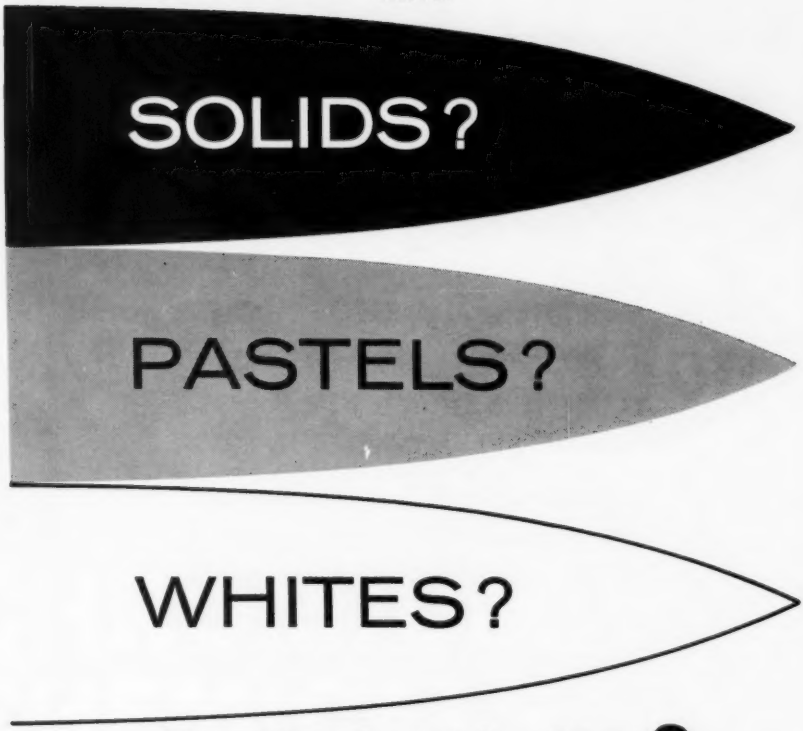

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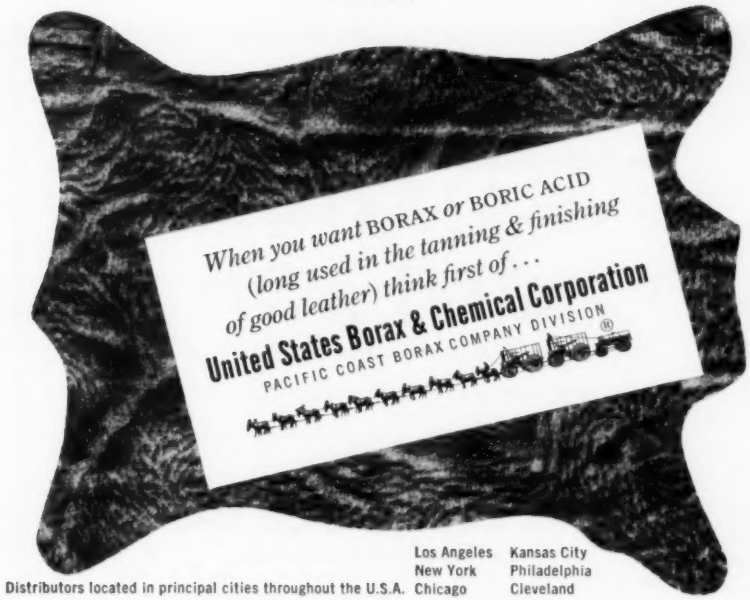
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INDEX TO ADVERTISERS

ADOLF SCHUBERT XXXI
ALLIED CHEMICAL CORP., Solvay Process Division ..... XXVII—XXIX
APEX CHEMICAL CO., INC. XXXIV
ARKANSAS COMPANY, INC. X
ARMOUR LEATHER CO. XXX
ARTHUR C. TRASK CO. VII
ARTHUR THOMAS CO. XVIII
ATLAS REFINERY XXIII
BARKEY IMPORTING CO., THE XV
BAY STATE OIL PRODUCTS XXX
BONA ALLEN, INC. XXXI
CALGON COMPANY XXXV
CHEMICAL COATING MATERIALS CO. XXVI
CHEMTAN COMPANY ..... Outside Back Cover
COLUMBIA-SOUTHERN CHEMICAL CORP. XX
COMET CHEMICAL CO., INC. XXXIII
COMMONWEALTH LABORATORIES, INC. XXXVI
DIAMOND ALKALI COMPANY XXIV
EASTERN INDUSTRIAL OIL PRODUCTS CO. XXXII
EISENDRATH TANNING CO. XLI
FIBER CHEMICAL CORPORATION XL
GARDEN STATE TANNING, INC. XLI
GEIGY COMPANY, INC. XI
GENERAL DYESTUFF COMPANY IX
HOOKER CHEMICAL CORP. III
HOWES LEATHER CO., INC. XXXI
INTERNATIONAL PRODUCTS CORPORATION XXV
INTERNATIONAL SALT CO., INC. XXII
JOHNSON AND CARLSON XL
KEPEC CHEMICAL CORPORATION XLI
LEATHER AND SHOES XXVIII
LEATHER MANUFACTURER, THE XXXIV
L. H. HAMEL LEATHER CO. XXXIII
L. H. LINCOLN & SON, INC. V
LOWELL TECHNOLOGICAL INSTITUTE XXXVII
MARDEN WILD CORPORATION XXXVIII
MARSHALL LABORATORY XXXVIII
NEWARK LEATHER FINISH CO. XXXIX
NOPCO CHEMICAL CO. XIX
OHIO LEATHER CO., THE XXXVII
OLSON IMPORTING COMPANY, INC., THE ..... Inside Front Cover
PRESTO COLOR CO. XXXIX
PRIME LEATHER FINISHES CO. XLI
PROCTOR AND SCHWARTZ, INC. XXXII
REILLY-WHITEMAN-WALTON CO. XXXV
ROBESON PROCESS CO. II
ROHM & HAAS IV
SALEM OIL & GREASE CO. XXXVI
SANDOZ, INC. XVII
SAXE CUTCH CORPORATION XXXIII
SEABOARD CHEMICALS, INC. ..... Inside Back Cover
SOCONY MOBIL OIL CO., INC. XIII
TANIMEX CORPORATION ..... XII—XVI
TANNADE COMPANY XL
TANNER'S COUNCIL RESEARCH LABORATORY ..... XXX—XXXVII—XLI
TANNINS & CHEMICALS, INC. VI
UNITED STATES BORAX & CHEMICAL CORP. XXXIII
WALLERSTEIN COMPANY, INC. XXI
WARNER CO. XXXVIII
WEBER & SMITH, INC. XXXI
WHITTEMORE-WRIGHT CO. XXXIX
WOLF, JACQUES & CO. VIII
YOUNG CO., J. S. XIV

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